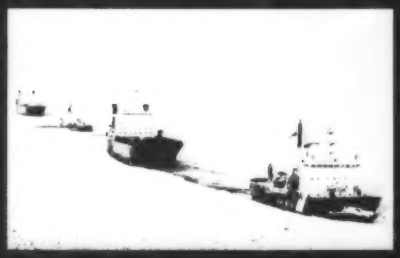

# Risk-based Design Method for **Aids to Navigation** in the St. Lawrence River

TP 13468E

Canada

100-03323/

TP 13468E

# Risk-based Design Method for Aids to Navigation in the St. Lawrence River

Prepared by

B. Judson
GeoInfo Solutions Ltd.

J. Shortreed
Institute for Risk Research, University of Waterloo

J.D. Reid
Transportation Development Centre, Transport Canada

August 1999

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Since the accepted measures in the marine industry are metric and imperial, both measures are used in this report where appropriate.

**Project Team**

James Reid, Transportation Development Centre, Transport Canada
Brad Judson, GeoInfo Solutions Ltd.
John Shortreed, Institute for Risk Research
Stéphane Julien, Canadian Coast Guard

**Acknowledgements**

The authors wish to acknowledge the outstanding contribution of Captain Stéphane Julien, Canadian Coast Guard/Department of Fisheries and Oceans, Laurentian Region, who led discussions with key stakeholders, developed the voyage plans for each route segment studied and completed the analysis of each segment using the MSD application. Capt. Julien's leadership, strategic approach and pathfinding contributions were invaluable to the project team.

The authors acknowledge the key contributions of Louis Rhéaume, President of the Lower St. Lawrence Pilots Corporation. Mr. Rhéaume was instrumental in applying his local knowledge of the waterway and pilotage best practices in ground-truthing the MSD tool.

Thanks are also extended to:

- DFO/CCG Laurentian Region Aids-to-Navigation and Waterways Program Staff
- Laurentian Pilotage Authority Canada
- Central Region Pilots Corporation
- Lower St. Lawrence Pilots Corporation
- St. Lawrence Ship Operators Association and member companies

Ce document est également disponible en français : *«Méthode de conception fondée sur le risque pour les aides à la navigation sur le fleuve Saint-Laurent»*, TP 13468F.

Transport Canada / Transports Canada

# PUBLICATION DATA FORM

| 1. Transport Canada Publication No. | 2. Project No. | 3. Recipient's Catalogue No. |
|---|---|---|
| TP 13468E | 9307 | |

| 4. Title and Subtitle | 5. Publication Date |
|---|---|
| Risk-based Design Methods for Aids to Navigation in the St. Lawrence River | August 1999 |
| | 6. Performing Organization Document No. |

| 7. Author(s) | 8. Transport Canada File No. |
|---|---|
| B. Judson, J. Shortreed, and J.D. Reid | ZCD2450-C-362-2 |

| 9. Performing Organization Name and Address | 10. PWGSC File No. |
|---|---|
| GeoInfo Solutions Ltd.<br>Institute for Risk Research, University of Waterloo<br>Transportation Development Centre, Transport Canada | HAL-7-40534 |
| | 11. PWGSC or Transport Canada Contract No. |
| | T8200-7-7552 |

| 12. Sponsoring Agency Name and Address | 13. Type of Publication and Period Covered |
|---|---|
| Transportation Development Centre (TDC)<br>800 René Lévesque Blvd. West<br>Suite 600<br>Montreal, Quebec<br>H3B 1X9 | Final |
| | 14. Project Officer<br>James D. Reid<br>E-mail: *reidj@tc.gc.ca* |

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Funded by the Department of Fisheries and Oceans (DFO)

16. Abstract

This project builds on expertise developed in the Arctic Tanker Risk Analysis and Canso research projects. Before the completion of this project, no analytical tool was capable of measuring the relative safety benefits of a particular configuration of aids to navigation in a complex waterway, such as a river with a dredged main channel.

The aim of this project was to enhance the Canso 99.9% preprocessor so that it was capable of measuring differences in navigational safety in the St. Lawrence River in a precise, track by track, method. The result was the minimum safe design (MSD) Excel program. The MSD program was developed with significant input from pilots, masters and Canadian Coast Guard captains. A preliminary risk analysis of traffic and accident frequency in the Laurentian Region was completed to compare the results of the MSD program to the historical record. A detailed risk assessment with a consequence analysis for the waterway between Lac St. Pierre and Trois Rivières was completed to illustrate the extent of potential human and environmental impact of an oil spill and a gasoline release event.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Risk analysis, St. Lawrence River, aids to navigation, shiphandling, pilotage, level of service, mariner's best practice | Limited number of copies available from the Transportation Development Centre<br>E-mail: *tdccdt@tc.gc.ca* |

| 19. Security Classification (of this publication) | 20. Security Classification (of this page) | 21. Declassification (date) | 22. No. of Pages | 23. Price |
|---|---|---|---|---|
| Unclassified | Unclassified | — | xx, 56, apps | Shipping/ Handling |

Transports Canada / Transport Canada

# FORMULE DE DONNÉES POUR PUBLICATION

| 1. N° de la publication de Transports Canada | 2. N° de l'étude | 3. N° de catalogue du destinataire |
|---|---|---|
| TP 13468E | 9307 | |

| 4. Titre et sous-titre | 5. Date de la publication |
|---|---|
| Risk-based Design Methods for Aids to Navigation in the St. Lawrence River | Août 1999 |
| | 6. N° de document de l'organisme exécutant |

| 7. Auteur(s) | 8. N° de dossier - Transports Canada |
|---|---|
| B. Judson, J. Shortreed et J.D. Reid | ZCD2450-C-362-2 |

| 9. Nom et adresse de l'organisme exécutant | 10. N° de dossier - TPSGC |
|---|---|
| GeoInfo Solutions Ltd.<br>Institute for Risk Research, University of Waterloo<br>Centre de développement des transports, Transports Canada | HAL-7-40534 |
| | 11. N° de contrat - TPSGC ou Transports Canada |
| | T8200-7-7552 |

| 12. Nom et adresse de l'organisme parrain | 13. Genre de publication et période visée |
|---|---|
| Centre de développement des transports (CDT)<br>800, boul. René-Lévesque Ouest<br>Bureau 600<br>Montréal (Québec)<br>H3B 1X9 | Final |
| | 14. Agent de projet<br>James D. Reid<br>Courriel : *reidj@tc.gc.ca* |

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Projet financé par le ministère des Pêches et des Océans (MPO)

16. Résumé


Ce projet s'appuie sur l'expertise acquise lors du projet *Analyse des risques inhérents à la navigation arctique* et de l'étude sur le détroit de Canso. Il vient combler l'absence, à ce jour, d'un outil d'analyse permettant d'évaluer les avantages relatifs, sur le plan de la sécurité, d'une configuration donnée d'aides à la navigation dans une voie d'eau complexe, tel un fleuve comportant un chenal principal dragué.

Le but de ce projet était de parfaire le préprocesseur 99,9 % mis au point lors de l'étude Canso pour qu'il puisse mesurer de façon précise, tronçon par tronçon, le niveau de sécurité associé à différentes configurations d'aides à la navigation dans le Saint-Laurent. Ces travaux ont abouti au programme Excel dit de «design minimum de sécurité» (DMS). Le développement de ce programme doit énormément à l'apport de pilotes, d'officiers et de capitaines de la Garde côtière canadienne. Les chercheurs ont mené une première analyse du risque associé au volume du trafic et à la fréquence des accidents dans la région Laurentienne, afin de pouvoir comparer les valeurs établies par le programme DMS aux données historiques. Une évaluation approfondie du risque, assortie d'une analyse des conséquences, a ensuite été effectuée pour la portion du fleuve reliant le lac Saint-Pierre et Trois-Rivières, afin d'illustrer la gravité des conséquences éventuelles sur le milieu humain et naturel d'un déversement de pétrole ou d'essence.


| 17. Mots clés | 18. Diffusion |
|---|---|
| Analyse du risque, fleuve Saint-Laurent, aides à la navigation, manœuvre du navire, pilotage, niveau de service, bonne pratique du marin | Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.<br>Courriel : *tdccdt@tc.gc.ca* |

| 19. Classification de sécurité (de cette publication) | 20. Classification de sécurité (de cette page) | 21. Déclassification (date) | 22. Nombre de pages | 23. Prix |
|---|---|---|---|---|
| Non classifiée | Non classifiée | — | xx, 56, ann. | Port et manutention |

## Executive Summary

### Background

The Short-Range Aids to Navigation Modernization Plan was introduced in the autumn of 1996 following intense budgetary reduction pressures within the Canadian Coast Guard (CCG). Among the various cost-cutting measures investigated was the level of service (LOS) for conventional aids to navigation. The short-range aids availability for the worst month of the year was reduced from 85 percent to 75 percent.

In 1994 and 1995 the maritime community stakeholders, shipowners and pilots met with the CCG to announce the results of their independent analyses regarding aids to navigation that could be removed or modified in the Laurentian Region. The second stage entailed a preliminary LOS analysis to evaluate the pertinence of each stakeholder's position regarding changes to the configuration of aids to navigation. Given the context of financial pressures and partial cost recovery from users, a major divergence of opinion emerged. The Canadian Shipowners Association and the St. Lawrence Shipowners Association agreed to the removal of 44 percent of commercial lighted buoys while the Central and Lower St. Lawrence Pilotage Corporations proposed a reduction of only 12.5 percent.

Within this discussion framework, negotiations could not proceed. It was felt that the divergent opinions of waterway users would only be further accentuated if the LOS adopted could not be justified based on mariner's best practice (MBP). We have adopted a structured approach in analysing the differences between identified needs and the theoretical LOS. This approach will enable the CCG to justify a short-range aids system that ensures navigation safety without increasing navigation complexity on the St. Lawrence River, while facilitating seaborne trade.

The approach employed in this study consists of a navigation risk analysis, following on from the Canso Strait study where navigation risk was quantitatively assessed based on the availability of short-range aids to navigation. The method allows risk estimates to be established based on historical casualty rates as a function of the short-range aids configuration and the potential accident consequences (losses). However, the Canso model was not directly applicable to the St. Lawrence given the major differences in navigation conditions in these two waterways. This tool was developed into the minimum safe design (MSD) pre-processor. The calculated safety zone around the ship now includes numerous improvements to measure navigational differences in a waterway. With the MSD tool, a short-range aids configuration can be designed to meet the LOS calculated for each route segment along the river.

To ensure that the results from this project were acceptable to all St. Lawrence River mariners and stakeholders, stakeholders participated throughout the project to assist in calibrating the model. They provided the needed feedback to help incorporate their best navigation practices and knowledge of the particular conditions into the risk-based model.

**Methodology**

In applying MSD techniques to the decision-making process for aids to navigation LOS, we sought to strike a balance between waterway safety and efficiency. To ensure this balance, an exhaustive description of the vessel characteristics, the waterway, climatic conditions and mariner experience/human factors was required.

The relationships between channel width (CW), shiphandling and navigation are based on documents such as "Approach Channels – A Guide for Design", International Association of Ports and Harbours; "Manoeuvring Guidelines for Navigable Waterways", CCG; and "Procedures Manual for Design and Review of Marine Short-Range Aids to Navigation Systems", CCG. The design approach builds on the Canso Strait study, which considered the CW provided relative to the MSD for the plausible worst case situation that the mariner may face defined as a probability of about 1 in 1000 transits of the channel. The risk is estimated by the relationship between the ratio CW/MSD and observed accident frequencies.

The study team, with input of local knowledge from pilots and masters, developed a conceptual design. Configuring and testing of the MSD structure by CCG officers and subject matter experts considered the complexities of navigation in the St. Lawrence River. This led to the development of a working prototype.

To summarize, significant input from professional mariners has guided the MSD development and its configuration for the St. Lawrence River. However, fine-tuning will be required to enable the MSD tool to respond to situations and gaps in functionality. The experience and expertise of the river pilots, CCG navigators and merchant vessel captains were captured to the fullest possible extent in the development of MSD.

*Design requirements*

The MSD model for the St. Lawrence, compared to the Canso MSD method, must reflect the complexity of the St. Lawrence, but at the same time be easier to understand, both for the designers and for the stakeholders. This was achieved through:

- A more detailed representation of MBP for shiphandling and positioning in a channel,

- A more detailed representation of the sections of the channel (e.g. specific turns, traverses, shoreline characteristics),

- A focus on the basic assumptions of the MSD model and a reduction of the display of arithmetic calculations,

- A hierarchical structure to the model use that considers the model components in bite-sized pieces that correspond to actual situations and locations on the river, and

- A data input requirement that is no more demanding than the current CCG LOS design process.

*MSD development approach – assisted by expert users*

The MSD method, illustrated in Figure 1, estimates the MSD for the CW, for specific time periods and river sections. The safe design is conditional on factors such as the design vessel, the aids to navigation configuration and the skill and knowledge of pilots and captains.

The MSD is width of the channel required for safe navigation by a design vessel for the given conditions in the river section and time period. The MSD CW is composed of three basic widths that are independent of each other and added together. The three distance elements are:

- A physical width to allow for the vessel's beam and drift due to winds and currents,

- A width to allow for shiphandling about a desired course, manoeuvrability due to squat, the resistance of brash ice, passing distance and bank clearance, and

- A width to allow for positioning confidence. This distance considers the aids to navigation available in the time period, bridge performance, etc.

The safety level of each river section is examined given a suitable range of worst plausible navigation situations.

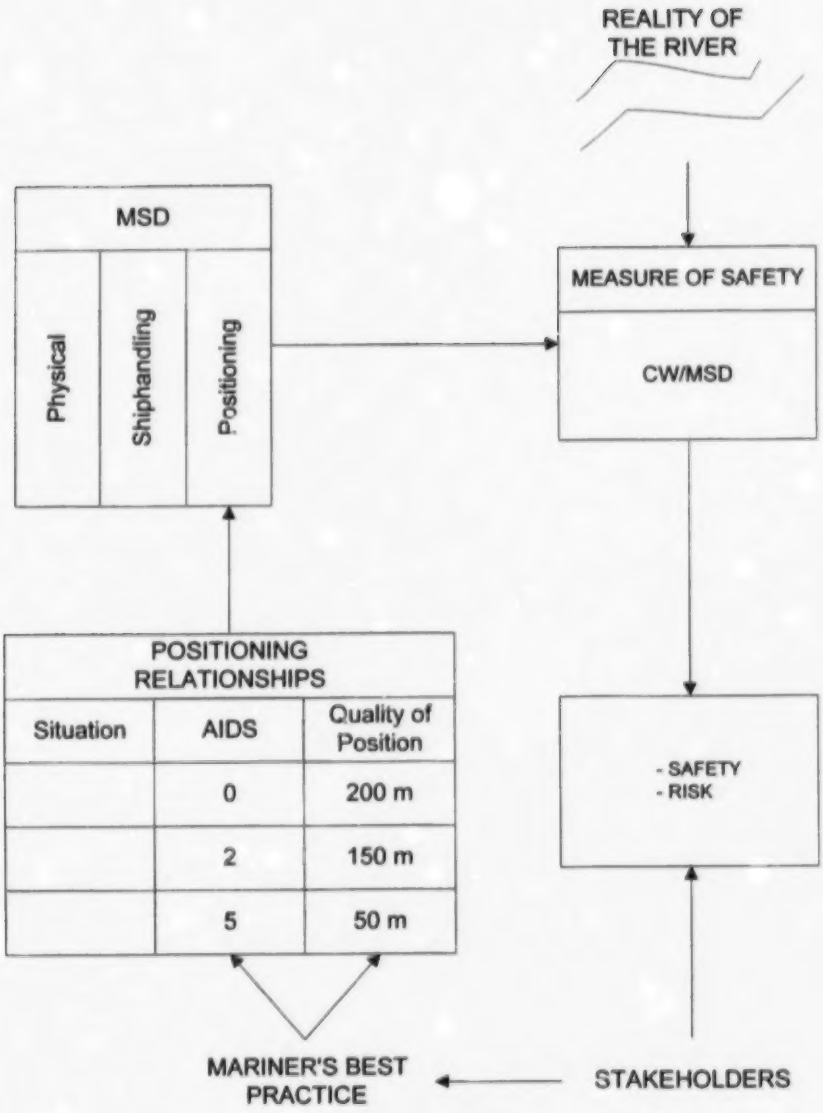


**Figure 1. Link between aids to navigation and risk in the MSD pre–processor**

**MSD Results**

*Goal*

The ultimate goal of the MSD approach is to examine the impact of changes in aids to navigation on waterway safety in keeping with the primary objective of balancing safety with marine transportation efficiency, while ensuring environmental protection.

*Validation of MSD method*

Comparisons of the MSD and CW data to accident data indicate the expected relationship between CW/MSD and accident rates for the areas studied (see Figure 2).

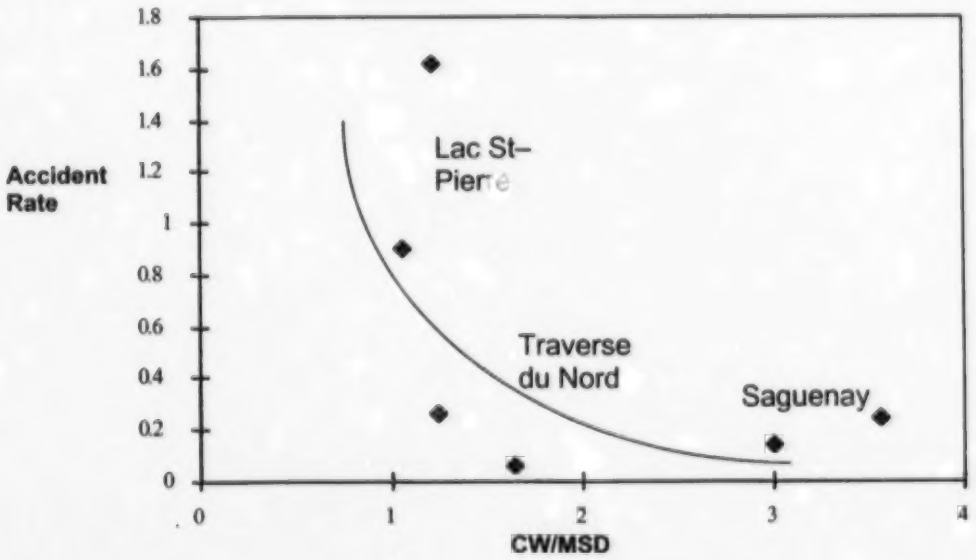


**Figure 2. CIP Accident Rate versus CIP median CW/MSD ratio**

Validation of the MSD method using accident data was limited by the available data. This is good for marine safety. It is unlikely that sufficient accident data will

ever be available and it will be necessary to continue to incorporate expert opinion into the MSD method.

The MSD method results are correlated to existing practice and this, along with the positive reception from stakeholders, suggests that the MSD method provides a systematic and logical method for assessing safety requirements and the level of risk on the river.

*Application of the MSD tool to the St. Lawrence River*

The number of river sections for which MSD values have been estimated is limited. Eventually, as the MSD method is used, estimates for most parts of the river should be made for most conditions. One direct comparison of the impact of the configuration of aids to navigation is provided in Table 1. This shows an increased risk in the Course Pointe du Lac with the removal of aids in an Association des armateurs du St-Laurent (AASL) scenario.

**Table 1. Comparison of the Bi–directional CW/MSD Ratios for Two Aids Configurations in Courbe Pointe du Lac**

| | | Channel width / MSD ratio | | |
|---|---|---|---|---|
| Section number | Section name | AASL Aids | Existing Aids | Change |
| 1 | R/M – C–63 | 1.40 | 1.40 | |
| 2 | Pont Laviolette | **0.77** | **0.77** | |
| 3 | Pointe–des–Ormes – St. François | 1.20 | 1.60 | |
| 4 | Courbe Nicolet | 1.28 | 1.28 | |
| 5 | Courbe Pointe du Lac | 1.06 | 1.06 | |
| 6 | Course Pointe du Lac | **0.89** | 1.23 | **–28%** |
| 7 | Course Pointe du Lac | **0.94** | 1.07 | **–12%** |
| 8 | R/M S–54 | **0.95** | **0.95** | |

Conditions: summer, one nmi visibility, two container vessels

*Accident rates*

A detailed analysis of marine casualty rates in the St. Lawrence River was conducted (see Table 2). Some observations of the accident analysis include:

- Of the sample of 137 accidents analysed in the Laurentian Region, 30 percent were collisions and 60 percent were groundings,
- Most of the accidents involved bulk carriers and cargo vessels, followed by oil and petroleum product tankers,
- The highest accident rates occur in Grondines and Pointe-des-Ormes, where one could expect an accident (probably a grounding by a bulk carrier or cargo vessel) with a "high damage degree" about once every five years, and
- Summer accident rates are significantly lower than winter rates.

## Table 2. Annual Accident Rates by CIP Area and Damage Degree

| CIP Area | | | | | Total | | Breakdown by Damage Degree *** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual | Length | Traffic nmi | Accident | Annual | High | | Medium | | Low | |
| # | Name | Traffic Count (95/96)** | (nmi, rounded) | (Count x nmi actual) | (Count per 22.5 years) | Accident RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* |
| 5 | ESCOUMINS | 4 857 | 17 | 81 112 | 3 | 0.16 | 0 | 0.00 | 0 | 0.00 | 3 | 0.16 |
| 6 | HAUT–FOND PRINCE | 4 928 | 13 | 65 542 | 2 | 0.14 | 2 | 0.14 | 0 | 0.00 | 0 | 0.00 |
| 7 | ILE BLANCHE | 4 871 | 11 | 55 042 | 3 | 0.24 | 0 | 0.00 | 2 | 0.16 | 1 | 0.08 |
| 0 | CAP AU SAUMON | 4 849 | 19 | 90 676 | 1 | 0.05 | 1 | 0.05 | 0 | 0.00 | 0 | 0.00 |
| 8 | CAP–AUX–OIES | 4 876 | 21 | 102 396 | 1 | 0.04 | 0 | 0.00 | 0 | 0.00 | 1 | 0.04 |
| 9 | GRAND–POINT | 4 866 | 16 | 77 856 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 10 | CAP BRULE | 4 869 | 14 | 69 627 | 4 | 0.26 | 2 | 0.13 | 0 | 0.00 | 2 | 0.13 |
| 11 | ST. LAURENT | 4 923 | 16 | 78 768 | 1 | 0.06 | 0 | 0.00 | 0 | 0.00 | 1 | 0.06 |
| 13 | QUEBEC | 4 488 | 10 | 44 431 | 23 | **2.30** | 1 | 0.10 | 7 | **0.70** | 10 | **1.00** |
| 14 | ST. AUGUSTIN | 4 535 | 12 | 53 967 | 8 | 0.66 | 4 | **0.33** | 3 | 0.25 | 1 | 0.08 |
| 15 | DONNACONA | 4 535 | 14 | 62 130 | 6 | 0.43 | 0 | 0.00 | 2 | 0.14 | 3 | 0.21 |
| 16 | GRONDINES | 4 538 | 14 | 61 263 | 17 | **1.23** | 5 | **0.36** | 3 | 0.22 | 8 | **0.58** |
| 17 | BATISCAN | 4 557 | 16 | 72 912 | 13 | 0.79 | 2 | 0.12 | 1 | 0.06 | 10 | **0.61** |
| 19 | POINTE–DES–ORMES | 4 321 | 15 | 63 087 | 23 | **1.62** | 5 | **0.35** | 7 | **0.49** | 9 | **0.63** |
| 20 | YAMACHICHE | 4 354 | 10 | 44 411 | 9 | 0.90 | 2 | 0.20 | 4 | **0.40** | 3 | 0.30 |
| 21 | ILE DES BARQUES | 4 357 | 14 | 62 305 | 11 | 0.78 | 0 | 0.00 | 2 | 0.14 | 7 | 0.50 |
| 22 | TRACY | 4 080 | 12 | 50 592 | 4 | 0.35 | 0 | 0.00 | 0 | 0.00 | 4 | 0.35 |
| 24 | CAP ST. MICHEL | 4 179 | 11 | 45 969 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 25 | MONTREAL EST | 4 424 | 9 | 38 046 | 8 | 0.93 | 2 | 0.23 | 0 | 0.00 | 5 | **0.58** |
| Grand Total | | | | 1 220 132 | 137 | 0.50 | 26 | | 31 | | 68 | |
| CASUALTY TYPE | | | | | | | | | | | | |
| Collisions | | | | | 41 | | 4 | | 18 | | 12 | |
| Groundings | | | | | 80 | | 21 | | 6 | | 49 | |
| Strikings | | | | | 16 | | 1 | | 7 | | 7 | |
| Mean | | | | | | 0.58 | | 0.11 | | 0.14 | | 0.28 |
| Standard Deviation | | | | | | 0.62 | | 0.13 | | 0.20 | | 0.29 |
| Mean + 1 SD | | | | | | 1.20 | | 0.24 | | 0.34 | | 0.57 |

*e.g., for ESCOUMINS: 4857 x 16.7 =81 112 vessel miles per year. 3/22.5 = .13 accidents per year or per 81 112 nmi, or .16 accidents per 100 000 nmi traveled. Accident data from 1/20/75 to 7/7/97.

** Includes all merchant vessels except for ferries for one year (95–96).

*** For 9% of the set of 137 records, damage degree is "unknown". These records are included in the grand total only.

The CIP areas with rates more than 1 SD above the mean are shown in bold typeface.

**Consequence analysis**

The consequence analysis component of the project addressed the worst plausible outcomes from a marine shipping scenario on the St. Lawrence River. The 1996 Data Archive and Distribution System (DADS) database was reviewed to determine the commodities shipped and the frequency of shipment. An initial examination of the data revealed that the list of hazardous products carried included many different petrochemical products out of the 71 category groupings. Bunker C heavy fuel oil was number 11 on the list (ordered by trip frequency) with 92 trips, and gasoline was number 12 with 87 trips. These two commodities were retained for study under an oil spill scenario and a fire/explosion scenario, both within the Lac St. Pierre segment of the river.

*Oil spill scenario*

A product tanker carrying bunker C heavy fuel oil collides with another vessel in the Pointe-du-Lac turn of Lac St. Pierre. This causes a 1 350 $m^3$ oil spill which affects numerous shoreline resources (see Figure 3).

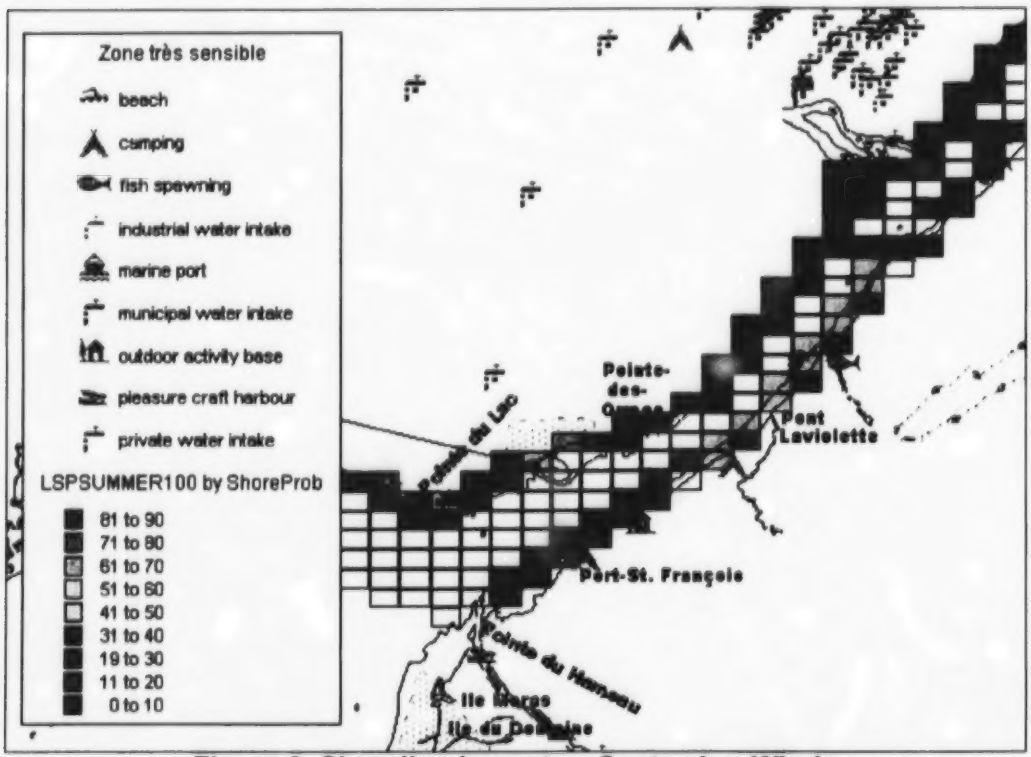


**Figure 3. Shoreline Impacts – September Winds**

The consequence magnitude for the oil spill scenario in Lac St. Pierre was measured as a probability of a spill of 1 350 $m^3$ given a collision. This probability is 0.013. Therefore, the annual probability of a spill was measured as the annual

probability of a collision involving a tanker (.054) times the conditional probability of the spill (0.013). Given these estimates, one would expect a medium-sized oil spill once every 1 428 years or 0.0007 per year. (Note: this estimate is just for the Pointe-des-Ormes area.)

Infrastructure clean-up and other civil damages are likely to reach the level predicted in the *Arctic Tanker Risk Analysis* spill cost model – the highest category of civil damages cost of $1 700 000. Clean-up of the river and the shoreline environment would exceed $13.9 million; fines for environmental damage could reach the maximum $1 million; vessel damage, cargo and business loss could exceed $5 million. This brings the cost of a single 1 350 $m^3$ oil spill to $22.2 million. The annual oil spill cost in Pointe-des-Ormes is $15 580; however, vessel damages alone due to collisions would be incurred once every three years and the cost could be as high as $5.6 million per incident, or $2 million per year.

*Gas fire/explosion scenario*

A product tanker carrying gasoline collides with another vessel near the port of Trois Rivières while on Course Pointe-des-Ormes, causing a 1 350 $m^3$ gasoline release event.

The PHAST consequence modelling application was used to estimate impacts of the gasoline spill. Initially, the discharging of liquid cargo and results are computed and displayed for the possible outcomes for the mixture under study. For gasoline, three main outcomes are possible: a pool fire, a flash fire or an explosion. Each scenario produced an impact zone that would include industrial facilities and port infrastructure within the port of Trois Rivières. Of the various figures produced, a chart of the flash fire flame envelope was selected to show the extent of potential impact of the worst plausible case (see Figure 4). Flash fires are lethal to all inside the flame envelope.

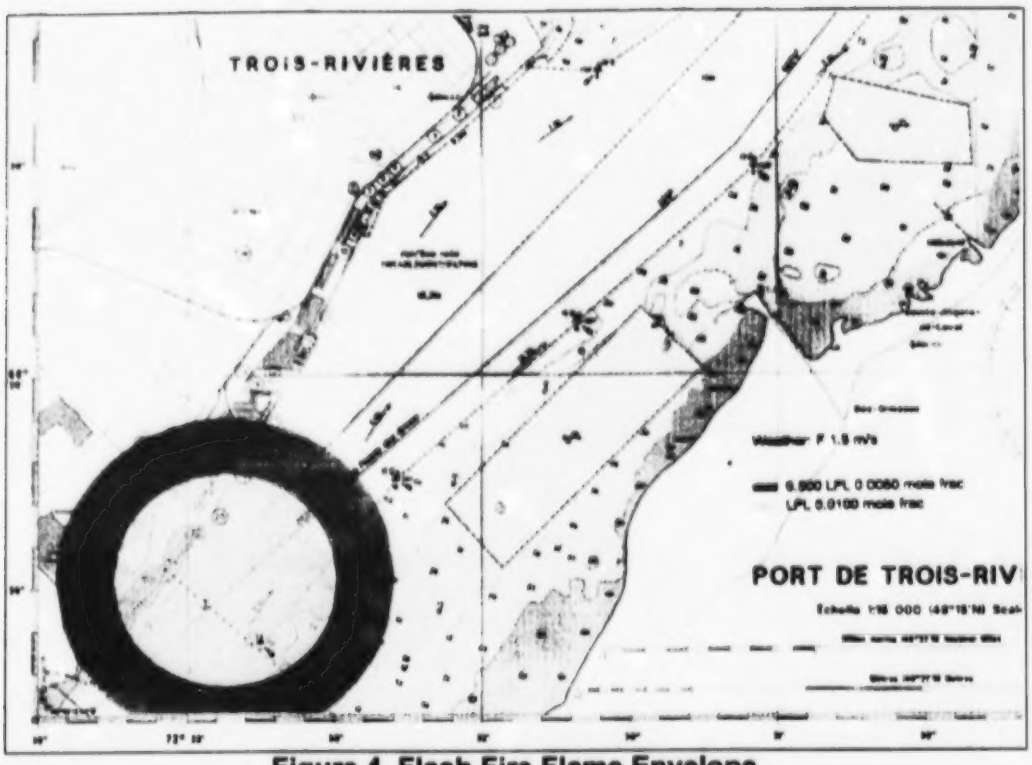


**Figure 4. Flash Fire Flame Envelope**

## Conclusions

- The MSD method and results reflect existing practice. This, along with the positive reception from stakeholders (including government and industry), suggests that the MSD method provides a systematic and logical way of assessing safety requirements and the level of risk on the river.

- Future inclusion of other accident causes in the MSD tool is possible if supported by evidence. As well, the design enables consideration of other navigation safety measures such as differential global positioning system (DGPS), electronic chart display and information system (ECDIS) and Marine Communications and Traffic Services (MCTS).

- The frequency of collisions involving through traffic in the Pointe-des-Ormes area was estimated as 8 in 22.5 years or 0.36 per year. There is a 15 percent chance that the vessel is an oil or oil product tanker (40/259).

- A valuation of the tanker collision risk was provided to indicate the costs of one of many possible risk scenarios. If the oil spill cost is $22.2 million, the annual cost in Pointe-des-Ormes is $15 580; however, vessel

damages due to collisions would be incurred once every three years and the cost could be as high as $5.6 million per incident or $2 million per year.

- The MSD tool was used to make numerous comparisons between the effect of vessel type, navigation conditions and aids to navigation configurations on safety in the St. Lawrence River in the Laurentian Region. A change in the LOS of aids to navigation proposed by AASL will affect safety on the river and potential consequence costs. For example, a summer, low visibility scenario involving two container vessels in Course Pointe-du-Lac showed an increased risk of 28 percent.

**Recommendations**

- The MSD tool will be released to workshop members for further review. A log should be kept of any changes so that the positioning relationships can be modified to reflect expert opinion.

- In light of the MSD analysis results for the three study areas, which showed a change in risk depending on the LOS of aids to navigation, any changes to current provision of aids to navigation or pilotage services should consider an MSD analysis for the waterway in question.

- The development team should work with CCG to investigate the effect of electronic aids to navigation, such as DGPS with ECDIS, on the positioning quality component in the MSD tool.

- The MSD tool and the Marine Navigation Safety System (MNSS) should be used to estimate potential consequence costs for a section of river and these estimates should be compared to various LOS provision costs.

- CCG should continue to develop and incorporate additional expert judgment into the model by applying the MSD method to additional segments of the river. Validation of the MSD method using accident data was limited by the available data. It is unlikely that sufficient accident data will ever be available and it will be necessary to continue to incorporate expert opinion into the MSD method to refine the precision of MSD estimates and broaden its applicability to different waterways.

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## Glossary

| | |
|---|---|
| A/C or R/M | Alteration of course or route modifiée |
| CIP | Calling-in-point |
| DADS | Data Archive and Distribution System |
| LOS | CCG Level of Service |
| MBP | Mariner's best practice, i.e., what MSD mariners agree is acceptable |
| MCTS | Marine Communications and Traffic Services |
| MSD | Minimum safe design for a particular time period for a particular "worst plausible case" situation |
| Section | A single track (turn or straight) |
| Time period | One of six time periods for analysis:<br>• winter good visibility* day<br>• winter good visibility night<br>• winter poor visibility<br>• summer good visibility day<br>• summer good visibility night<br>• summer poor visibility |
| Traverse | A set of track segments or sections to analyse |
| Worst plausible case | For pilotage, e.g., winter, ice, wind from southeast |

*Note: Poor or good visibility is as defined in the CCG Preliminary Threat Rating Guide depending upon vessel type and location.

# 1 Introduction

## *1.1 Context*

The Short-Range Aids to Navigation Modernization Plan was introduced in the autumn of 1996 following intense budgetary reduction pressures that were experienced within the Canadian Coast Guard (CCG). Among the various cost cutting measures investigated was the level of service (LOS) for conventional aids to navigation. The short-range aids availability for the worst month of the year was reduced from 85 percent to 75 percent.

In 1994 and 1995 the maritime community stakeholders, shipowners and pilots met with the CCG in order to announce the results of their independent analyses regarding aids to navigation that could be removed or modified in the Laurentian Region. The second stage entailed a preliminary level of service analysis to evaluate the pertinence of each stakeholders position regarding changes to the configuration of aids to navigation. Given the context of financial pressures and partial cost recovery from users, a major divergence of opinion emerged. The Canadian Shipowners Association and the St. Lawrence Shipowners Association agreed to the removal of 44 percent of commercial lighted buoys while the Central and Lower St. Lawrence Pilotage Corporations proposed a reduction of only 12.5 percent.

Within this discussion framework, negotiations could not proceed any further. It was felt that the divergent opinions of waterway users would only be further accentuated if the LOS adopted could not be justified based on mariner's best practice. We have adopted a structured approach in analysing the differences between identified needs and the theoretical LOS. This approach will enable the CCG to justify a short-range aids system that ensures navigation safety without increasing navigation complexity on the St. Lawrence River, while facilitating seaborne trade.

The approach employed in this study consists of a navigation risk analysis, following on from the Canso Strait study where navigation risk was quantitatively assessed based on the availability of short-range aids to navigation. The method allows risk estimates to be established based on historical casualty rates as a function of the short-range aids configuration and the potential accident consequences (losses). However, the Canso model was not directly applicable to the St. Lawrence given the major differences in navigation conditions in these two waterways. This tool was developed into the minimum safe design (MSD) pre-processor. The calculated safety zone around the ship now includes numerous improvements to measure navigational differences in a waterway. With the MSD tool, a short-range aids configuration can be designed to meet the LOS calculated for each route segment along the river.

To ensure that the results from this project were acceptable to all St. Lawrence River mariners and stakeholders, they participated throughout the project to assist in calibrating the model. They provided feedback to help incorporate their best navigation practices and knowledge of the particular conditions into the risk-based model.

### *1.2 Background*

The relationships between channel width (CW), shiphandling and navigation are based on documents such as "Approach Channels – A Guide for Design", International Association of Ports and Harbours; "Manoeuvring Guidelines for Navigable Waterways", CCG; and "Procedures Manual for Design and Review of Marine Short-Range Aids to Navigation Systems", CCG. The design approach builds on the Canso Strait study, which considered the CW provided relative to the minimum safe design (MSD) for the plausible worst case situation that the mariner may face defined as a probability of about 1 in 1 000 transits of the channel. The risk is estimated by the relationship between the ratio CW/MSD and observed accident frequencies.

The St. Lawrence River is among the most difficult navigable waterways in the world, with a length of over 400 nmi between Les Escoumins and Kingston, many course changes, severe ice in winter, heavy traffic, channel widths near the minimum and restricted channel depth.

The scope of this study focused on the examination of the risk in three study areas: Lac St. Pierre, Traverse du Nord and the approaches to the Saguenay River. These areas pose unique challenges to navigation in winter and summer, and provide an excellent test bed for the MSD pre-processor development. Examples include: the "s" turn of Courbe Pointe du Lac and Courbe Nicolet, as well as the narrows of Pont Laviolette in the Lac St. Pierre study area; the moving ice and crosscurrent in proximity to buoy K108 in Traverse Nord and the strong crosscurrents and traffic interaction north of Ile Rouge in the Saguenay approaches.

The study team, with input of local knowledge from pilots and masters, developed a conceptual design. Configuring and testing of the MSD structure by Coast Guard officers and subject matter experts considered the complexities of the three study areas. This led to the development of a working prototype, as well as the identification of several relationships where further examination and input of expertise were required:

- Manoeuvring and vessel performance in ice,
- Manoeuvring and vessel type, and
- Positioning techniques.

To summarize, significant input from professional mariners has guided the MSD development and its configuration for the St. Lawrence River. However, fine-tuning will be required to enable the MSD tool to respond to situations and gaps in functionality. The experience and expertise of the river pilots, CCG navigators and merchant vessel captains were captured to the fullest possible extent in the development of MSD.

### *1.3 Objective*

The objective of the risk-based design method was to develop the MSD tool with the assistance of expert users (pilots, captains). In applying MSD techniques to the decision-making process for aids to navigation LOS, we sought to strike a balance between waterway safety and efficiency. To ensure this balance, an exhaustive description of the vessel characteristics, the waterway, climatic conditions, mariner experience/human factors, historical accident record and risk receptors was required.

The purpose of the MSD development was to assess the 99.9% pre-processor application to the St. Lawrence River and investigate the changes required to properly adapt the model to the St. Lawrence River scenarios and include the following characteristics:

- Ship manoeuvrability as a function of: ship type, speed, displacement, draft, freeboard, windage, under keel clearance including the effects of tides, water level and currents,
- Navigable channel sizes, type of channel bottom, squat, turns and anchorages,
- Environmental elements including currents (head, cross and following), winds, visibility, ice, day/night and winter/summer navigation,
- Human factors – best navigation practices (years of experience, pilotage and Marine Communications and Traffic Services (MCTS),
- Uni- and bi-directional traffic,
- Influence of specific short range aids to navigation and the total configuration within the route segment under study, and
- Type of cargo carried (i.e., loaded, ballast, container).

# 2 Requirements

## *2.1 Design Requirements*

The MSD model for the St. Lawrence, compared to the Canso 99.9% method, must reflect the complexity of the St. Lawrence, but at the same time be easier to understand, both for the designers and for the stakeholders. This was achieved through:

- A more detailed representation of MBP for shiphandling and positioning in a channel,
- A more detailed representation of the sections of the channel (e.g. specific turns, traverses, shoreline characteristics),
- A focus on the basic assumptions of the MSD model and a reduction of the display of arithmetic calculations,
- A hierarchical structure to the model use that considers the model components in bite-sized pieces that correspond to actual situations and locations on the river, and
- A data input requirement that is no more tasking than the current CCG LOS design process.

# 3 Understanding the MSD Method

The MSD method is closely related to the international approach of the Permanent International Association of Navigation Congresses (PIANC) (1), the International Association of Lighthouse Authorities (IALA) (2) and CCG (3), as well as the method used by the United States Coast Guard (USCG) (4). This allows the basic relationships in the method to be validated against other recognized authorities and existing practices.

To understand the MSD method, three contexts are considered:

- The design and policy environment for decisions on the channel and its level of service,
- The structure of the MSD method and its acceptance by stakeholders as being a valid representation of requirements for channel design, and
- Detailed relationships and parameter values for squat, vessel turning characteristics, effects of tides and currents, and other maritime fundamentals that govern the movement and safety of vessels.

These contexts are discussed in sections 3.1, 3.2 and 3.3.

## *3.1 The Design and Policy Environment*

The following statements and assumptions were identified at the MSD design stage to characterize the design and policy environment for MSD:

- The St. Lawrence River Channel should be designed for the "ultimate" design vessels that are possible given the natural limitations of the river, especially the depth of the river,
- The risk implications of very detailed changes in aids to navigation, or CW are of interest so that the change in risk can be weighed against the costs of the changes by the decision-makers and the stakeholders, e.g., implementation costs and consequence costs avoided such as oil spill clean-up. It is recognized that these estimates of the changes in risk will depend as much on expert opinion as on scientific analysis,
- The MSD method must be validated through consultation and dialogue with stakeholders. The dialogue must be based on "real" situations of specific design vessels in specific sections of the river, for specific times of the year and for typical "bridge" activities. The MSD method must be capable of effective and efficient risk communications,

- The MSD channel design is the minimum channel width acceptable to the stakeholders, for the specified conditions and operating rules. This acceptability is based on the "plausible worst case" situation that generally will be observed once on an annual basis. It does not consider the worst case imaginable or possible, but rather the probable worst case. Acceptability of stakeholders would be based on MBP,

- It is expected that there will be operating rules that will declare the channel "unavailable" or "available with restrictions" for two-way or even one-way traffic for specific conditions and situations (e.g. ice, wind, visibility, draught),

- The MSD method should be logical, have a rational framework, be easy to understand, be expandable to incorporate new and emerging technologies. Its development approach should use scientific methods. It should not be necessary to change the basic approach of the MSD method when faced with new policy issues,

- The variation in MSD CWs with different locations in the river should correspond, generally, to variations in the historical accident frequency observed for those locations. This should also be true for different seasons of the year, and time of the day, or night, when visibility is good or limited. This will provide some confidence in the method,

- The major decisions (involving best practice and operating conditions) by mariners, CCG (Marine Navigation Services, Marine Communications and Traffic Services) for the St. Lawrence, are limited to decisions about: the speed of the vessels, one-way versus two-way traffic, "no go" conditions, dredging of the channel, allowable vessels, number of pilots required, required navigational aids and provision of aids to navigation,

- It is assumed that expert mariners will be required to provide input to MSD given the inherent complexity of the river, the required speed of decisions that must be made for a safe passage, and the consequences of an accident, and

- These statements and assumptions should be amended or added to from background documents and the experience of subject matter experts.

### *3.2 The MSD Approach, Structure and Acceptance by Stakeholders*

The approach to the MSD method application is outlined in Figure 1. The policy environment – involving major policy questions such as dredged CW, aids to navigation, requirements for navigational aids and operational rules – is the main driving force for the method. The method is intended to provide information to assist decision-makers.

The "reality of the river" is a key element of the approach in Figure 1. The sections of the channel, the time periods (e.g. winter/summer, good visibility/poor visibility and day/night), the selection of the design vessel(s), characteristics of the river and the historical accident frequency combine to give a detailed realistic description of the river channel. This is necessary, since the risks and the provision of mitigation measures depend to a great extent on local knowledge and experience of the mariners. Without a detailed and realistic description of the channel, it is not possible to obtain input from the stakeholders and to evaluate alternative policies.

The stakeholders (CCG, pilots, ship owners, marine authorities, etc.) are essential to the success of applying the MSD method, since there is limited data for scientific analysis, and expert opinion must be used extensively. Stakeholder input is required for the completeness of the characterization of the channel, the logical validity of the MSD method, the relationships in the MSD method, the reasonableness of the estimated MSD, and verification of the relative risk estimates for the different sections and time periods.

As indicated in Figure 1, the MSD method estimates the minimum safe design for the channel width, for specific time periods and sections. The safe design is conditional on the design vessel, the aids to navigation provided, the skill and knowledge of the pilots, and so forth. The ratio of (CW/MSD) is compared to the observed accident frequency for each time period and section; if possible, however, it is likely that aggregation over sections and perhaps time periods will be required to make a statistically valid comparison and development of confirming relationships between (CW/MSD) and risk.

Once the MSD method is considered satisfactory by the stakeholders, it can be used to estimate the changes in risk levels under different policies. It should be noted that the comparison of MSD and CW can result in three outcomes for the specified design vessel:

- The section and time period is acceptable for two-way traffic,
- The section and time period is acceptable for only one-way traffic, and
- The section and time period is unavailable for use.

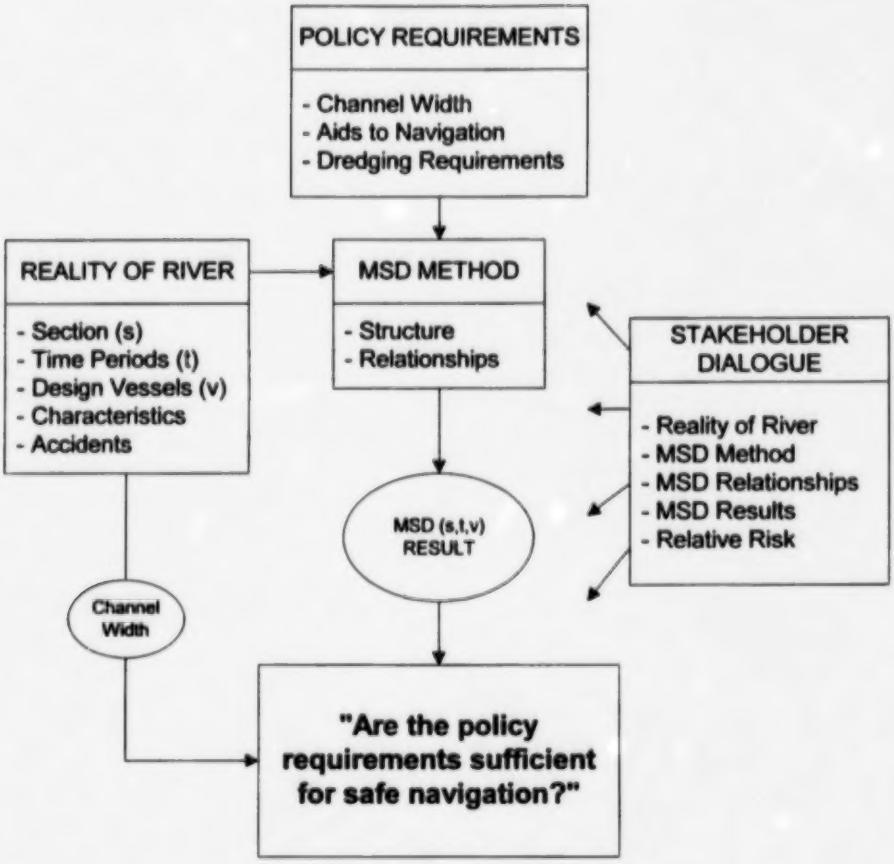



**Figure 1. MSD Approach**

Figure 1 indicates that the MSD method has two major components: the structure of the method, and the relationships within the method (also see Section 3.3).

Figure 2 illustrates the structure of the MSD method with the major output being the MSD for prevention of groundings. This is given as a distance of the width of the channel for the given conditions for the section and time period. The MSD CW is composed of three basic widths that are independent of each other and are added together. The three distance elements are:

- a physical width to allow for the vessel's beam and drift due to winds and currents,
- a width to allow for shiphandling about a desired course, manoeuvrability due to squat, the resistance of brash ice, passing distance and bank clearance, and
- a width to allow for positioning confidence. This distance considers the aids to navigation available in the time period, bridge performance, etc.

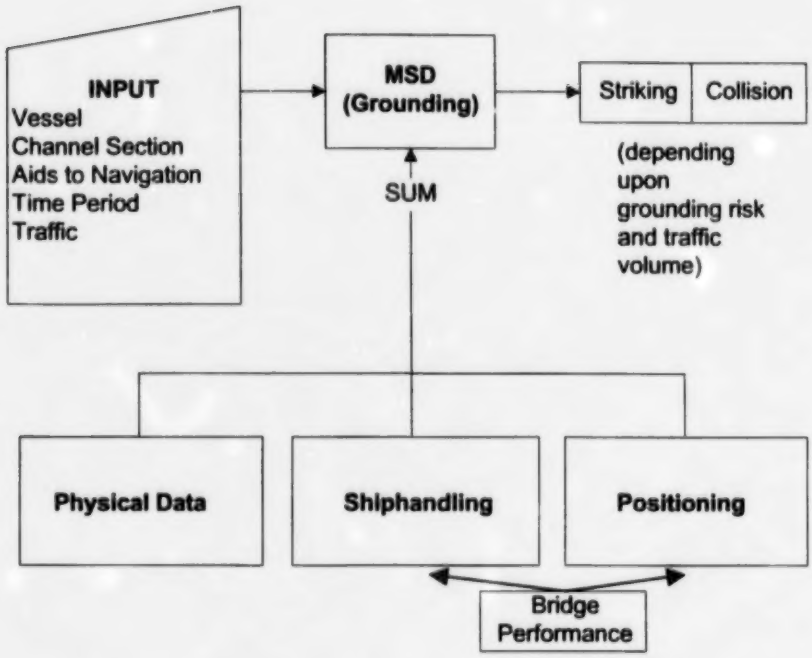



**Figure 2. Basic Structure of MSD Analysis**

The safety level of each river section is examined given a suitable range of worst plausible navigation situations.

The ultimate goal of the MSD approach is to examine the impact of changes in aids to navigation on waterway safety in keeping with the primary objective of balancing safety with marine transportation efficiency, while ensuring environmental protection.

### *3.3 MSD Relationships*

The standard relationships referred to in Figures 1, 3 and 4 were developed based on traditional maritime knowledge (e.g., rules of the road and methods used for positioning), on experience with the channel, measured performance of vessels, accident data and descriptions, etc. In each case the relationships were examined, validated or modified and then validated by the expert stakeholders.

Table 1 provides a checklist to show where each factor listed in the design objectives is addressed in specific sub-components in the MSD preprocessor. Note that:

- The MSD process requires the examination of these variables for each section, time periods (winter, summer, day, night, visibility) and design vessel(s), and

- Special consideration of the defined CW is required to correctly analyse separate one-way traffic routes in open water (e.g., the approaches to the Saguenay River).

## Table 1. Coverage of Design Factors by MSD Sub–component

| Variable | Course length, width, depth, etc. | Wind & current drift, vessel speed & beam | Squat, security margin & underkeel clearance | Passing distance, coursekeeping | Manoeuvring in ice | Squat effects and bank clearance | Positioning by radar & aids to navigation | Positioning by visual methods & aids to navigation |
|---|---|---|---|---|---|---|---|---|
| **Vessel** | | | | | | | | |
| course | X | X | | | | | | |
| speed | | X | X | | X | | | |
| displacement | | X | | | | | | |
| beam | | X | X | X | | X | | |
| draught | | X | X | | | | | |
| length | | X | | | | | | |
| windage or freeboard | | X | | | | | | |
| horsepower | | | | | X | | | |
| cargo | | | X | | | | | |
| navigation aids | | | | | | | X | X |
| squat & clearance | | | X | | | X | | |
| **Channel Section** | | | | | | | | |
| visibility | | | | X | | | X | X |
| natural targets | | | | | | | X | X |
| depth & tide | X | | X | | | X | | |
| navigable width | X | | X | | | X | | |
| bottom/bank profile and type | | | | | | X | | |
| turn/straight/anchorage | X | | | X | | | X | X |
| ice concentration | | | | | X | | X | X |
| relative wind speed and direction | | X | | | X | | | |
| relative current speed and direction | | X | | | X | | | |
| **Aids to Navigation** | | | | | | | | |
| buoys | | | | | | | X | X |
| ranges | | | | | | | X | X |
| fixed targets | | | | | | | X | X |
| **Bridge Performance** | | | | | | | | |
| workload, fatigue, ergonomics, resources | | | | X | | | X | X |

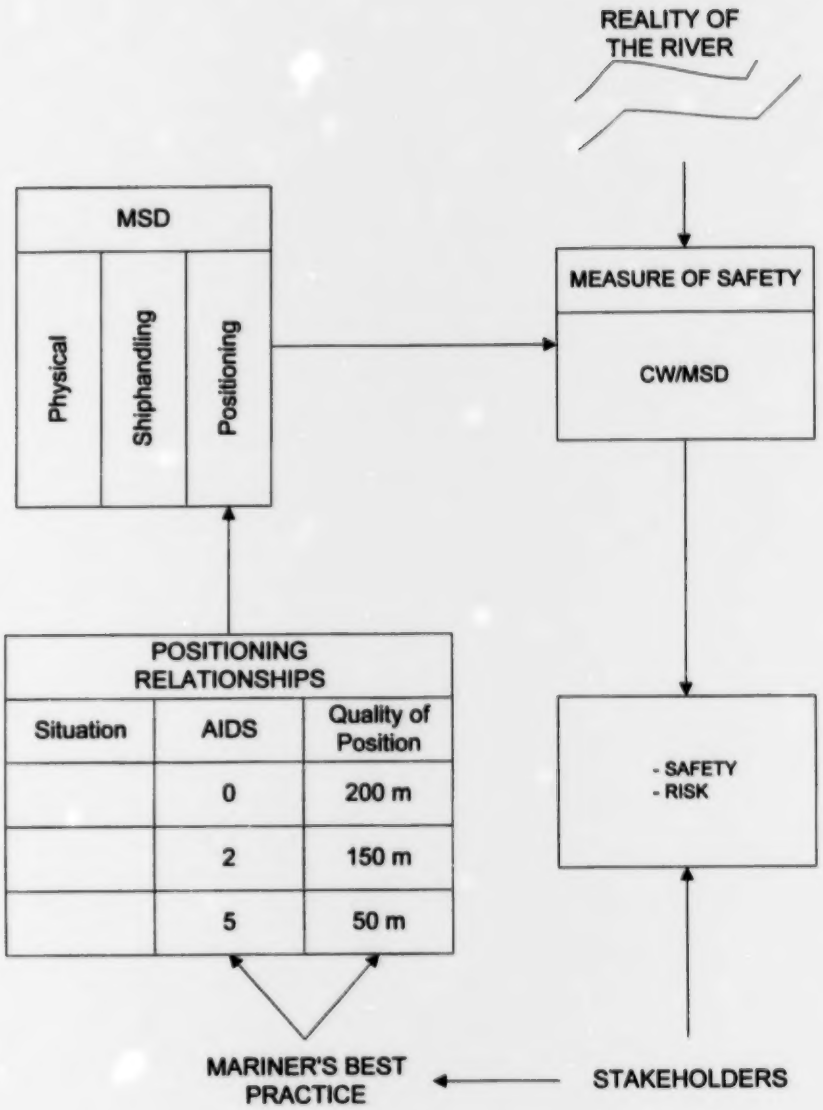



**Figure 3. Link Between Aids to Navigation and Risk in the MSD Pre–processor**

# 4 The MSD Channel Design or Analysis Process

The MSD method first estimates the required CW for one-way operation. This requires the input of data into the Excel MSD tool to estimate three components:

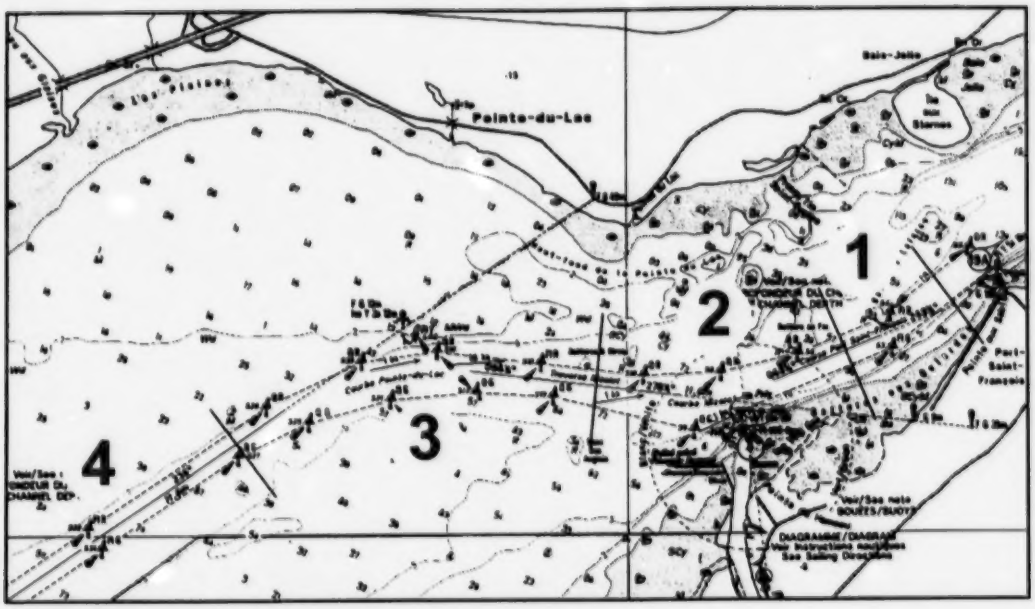
- physical dimensions,
- shiphandling, and
- positioning.

Next, the MSD is estimated for two-way operation based on the selection of a "plausible worst case" situation for the design vessel to be passed. The MSD method is used for the design vessel to be passed to estimate the one-way requirements and then both one-way requirements are combined and the redundant components, such as bank clearance removed and the passing separation added.

Upbound and downbound use of the channel are evaluated separately and the maximum MSD is used. Since most of the estimation procedure is identical for upbound and downbound traffic (with some differences, for example, the design vessel load status may change), the procedure is very efficient once one direction has been completed. In this and other mechanics of the MSD procedure the sequence of time periods, sections and design vessels are selected to maximize the ease of use and the capture of expert opinion.

Figure 4 illustrates the worksheet and procedure for applying the MSD method. The first step is to section the traverse being analysed using the available charts. Then the analyst records all the characteristics of the channel that affect the design vessel. This is done section by section in the direction of the transit. Then the stakeholders are consulted on the MSD and the three CW elements: physical dimension, shiphandling and positioning.

CHART




Design Vessel

Time Period & Conditions

WORKSHEET: 2-WAY TRAFFIC

| Section | Characteristics | Physical Dimension | Shiphandling | Positioning | Section MSD (SUM) |
|---|---|---|---|---|---|
| 1. Turn | | 252 | 740 | 100 | 1092 |
| 2. Turn | | 292 | 740 | 100 | 1132 |
| 3. Turn | | 282 | 740 | 100 | 1122 |
| 4. Straight | | 262 | 460 | 100 | 822 |

STAKEHOLDER
USE OF RELATIONSHIPS TO
ESTIMATE VALUES

RELATIONSHIPS

- Squat
- Turn Dynamics
- Radar Accuracy

**Figure 4. Procedure for MSD Method**

# 5 The Positioning Functional Relationship

Two processes are described in this section. They are defined as:

- *MSD channel design or analysis positioning accuracy estimation process*: "The process of selecting an appropriate aids to navigation configuration as part of an MSD design or MSD analysis", and

- *The process of developing positioning quality and navigation aids relationships*: "The process of developing a decision tree that describes the relationship between aids and positioning quality using expert navigation input".

## *5.1 Analysis of Positioning Accuracy and Aids Configurations*

Figure 5 shows how the positioning relationship would be used for design or analysis. The river situation for each section would be available from Figure 4 and this would include the identification of "good visual targets", such as church steeples, well-defined rock cliffs and hydro towers.

The "basic" aids to navigation for the given conditions are determined first by considering:

- Basic aids determined from previously considered time periods and visibility conditions;

- Additional targets (including Racons) required for:
  - confirming position,
  - locating turns and/or wheel over positions;

- Additional buoys required; and

- Ranges required.

Note that this is an iterative process since the ranges for one section will provide a range for the next section for vessels going in the opposite direction. Ranges that require a structure in the river will create a target. Buoys for other time periods and visibility conditions will already be a "basic" aid. Limited experience suggests that by considering section by section and then revisiting sections it is possible to reach an equilibrium set of basic aids in a reasonable time.

Once the basic aids for a section are defined, the positioning algorithm in the MSD tool automatically determines the positioning distances. Since positioning distance completes the estimation of the MSD CW, it is possible to compare it to

the actual CW through the ratio (CW/MSD). The (CW/MSD) ratio is automatically calculated for one- and two-way traffic.

If the (CW/MSD) ratio is not acceptable, the aids are enhanced and the positioning relationships are used to find the change in the positioning distance and the revised (CW/MSD) ratio is checked for acceptability. This process continues for either the one-way or two-way traffic until:

- (CW/MSD) is acceptable, or
- It is not practical to improve MSD any more and the availability of the channel is set to:
  - Available for two way (less than desired LOS),
  - Available for one way for time period, or
  - Unavailable for the time period.

When the two loops, A and B, are completed, loop C is used to consider another time period. The suggested order for considering time periods is:

- Winter, good visibility, day,
- Winter, good visibility, night,
- Winter, poor visibility,
- Summer, good visibility, day,
- Summer, good visibility, night, and
- Summer, poor visibility.

However, this order should be examined after more experience with the method.

Consistent with good optimization principles, enhanced aids to navigation should be considered along with changes in availability, widening of the channel by dredging, provision of enhanced pilotage, improvements in navigational aids (e.g. portable ECDIS for pilots), additional anchorages and other ways of improving safety.

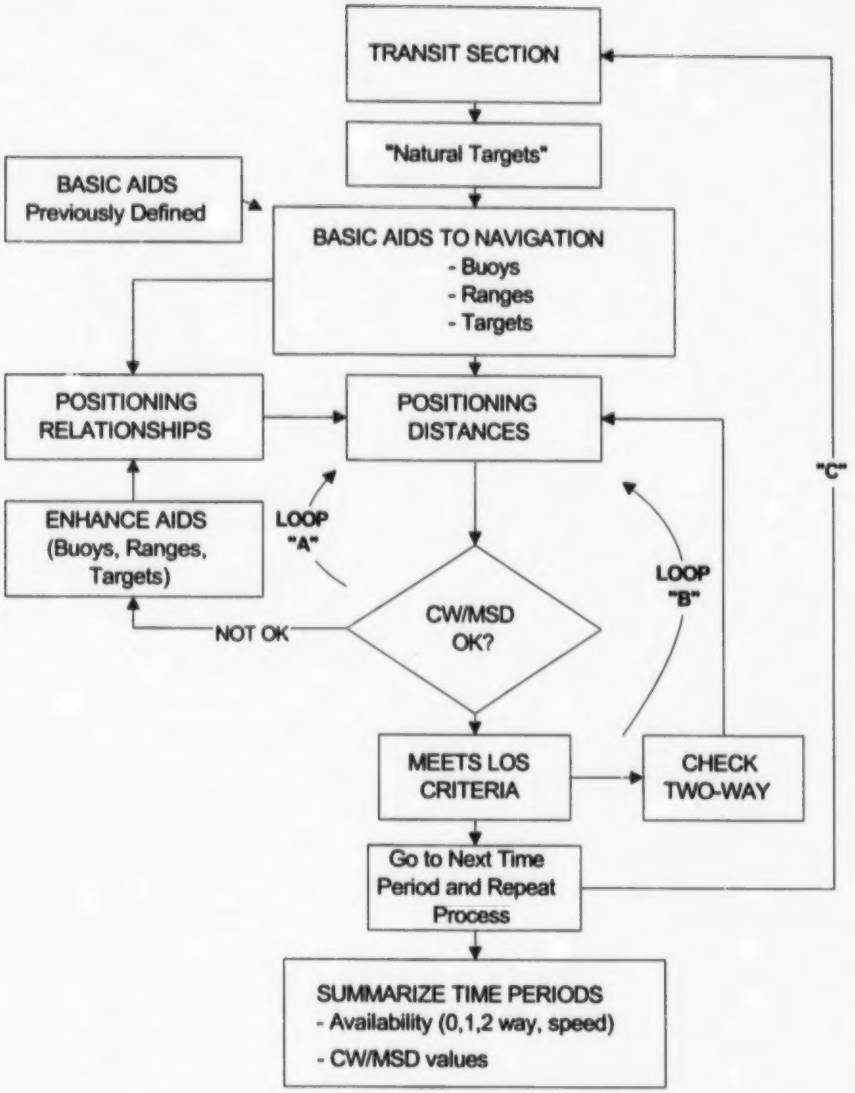



**Figure 5. Analysis of Positioning Quality**

## *5.2 Positioning Relationship and Accuracy Table Development Process*

### 5.2.1 Background

The development of relationships between aids to navigation and positioning quality was a critical step in the development of the MSD method. The PIANC document indicates that aids to navigation are "of crucial importance" to "define the width and alignment of the channel" but the PIANC design process suggests otherwise. Specifically, the range from moderate to excellent aid provision is from 0.5 beams to 0.0 beams (i.e., only a 50' range from moderate to excellent aids). However, this is not supported by MBP, or IALA. IALA correctly indicates that a 95% accuracy in a gyro bearing is equivalent to 1°, which, at one mile distance represents 100' in uncertainty in lateral position.

Experts with local navigation knowledge were able to examine the design of the MSD tool at several stages in workshops. While the final positioning quality decision tree was only reviewed once by pilots, masters and marine organizations, more review is planned as the MSD tool is released to workshop members for further review. A log should be kept of these changes so that the positioning relationships can be modified to reflect expert opinion.

The development process is described below. The method used to establish positioning accuracy relationships is illustrated in Figure 6.

### 5.2.2 The process

In order to develop a "scale" of positioning quality for the river that is consistent in its interpretation (basic, 1st enhancement, 2nd enhancement), but is also related to the situations and conditions in the river, a passage is planned, tracks are plotted on a chart and the waterway is subdivided into unique turn and straight sections. Some differences requiring a unique section include: a different method of navigation, a different depth, a different channel width and different currents. Refer to Appendix C for further indications of section subdivisions.

Ideally, each time period, as described in section 5.1, is examined and the aids to navigation are assessed for their positioning quality, beginning at a "basic" configuration and advancing, up to three enhancement levels. Figure 6 illustrates this process and indicates the method of checking for consistency of positioning quality estimation. At completion, the resulting "positioning relationship" table is created, a sample of which is shown in Table 2.

Basic aids to navigation are the minimal set of aids needed to comfortably transit a traverse of the river, under the given conditions for the time period. The aids are dependent on the characteristics of the river, such as length of straight,

degree of turn and cross currents, but are independent of the CW. The aids are grouped into seven categories.

Enhanced aids are not continuous (i.e., 1, 2, 3 or more aids), but are logical groupings of additional aids:

- That are considered in terms of incremental improvement in positioning from the basic set of aids,
- That are logical in terms of MBP; for example, if a basic turn marking consisted of two gated buoys at the turn and one buoy at each end marking the start of turn, then the first enhancement might be two additional buoys to create gated buoys at each end. Also, this increase from four to six buoys per turn would be repeated at all turns in the traverse. So, if there were, for example, four turns, the enhanced arrangements of buoys would be an increase of eight buoys,
- That have a noticeable difference in positioning (e.g. 20-30 m), so that an incremental enhancement is a noticeable step up in positioning accuracy (this sets a limit in the number of enhancements considered,
- That are selected from either: buoys, ranges or fixed targets (including Racons), and
- Where, if possible, the levels of enhancement are limited to two or three additional levels of aids to navigation.

Not enough time was available to examine all aids to navigation levels for each time period, vessel type and conditions. During this study, four types of configurations were examined under numerous conditions. These included: aids to navigation configurations for winter, summer, the present configuration and the configuration proposed for analysis by Association des armateurs du St-Laurent (AASL). There was sufficient time over the course of the project for five ship captains to examine over 100 unique sections or time periods and estimate positioning accuracies.

The characteristics for each section and its positioning quality were tabulated and sorted by the position quality in descending order. Then the sections were grouped into logical aids to navigation configurations where a common rule described the aids, visibility and method of navigation. At this point, there were discrepancies; these were examined and resolved, usually with the addition of another rule describing a unique situation.

Once the discrepancies were corrected, a functional relationship was developed from a decision tree with positioning quality estimates for each time period (*good visibility*: winter, summer, day, night; *poor visibility*: winter, summer). The

positioning function then responds to the aids to navigation configuration presented in the MSD tool and outputs a positioning quality value.

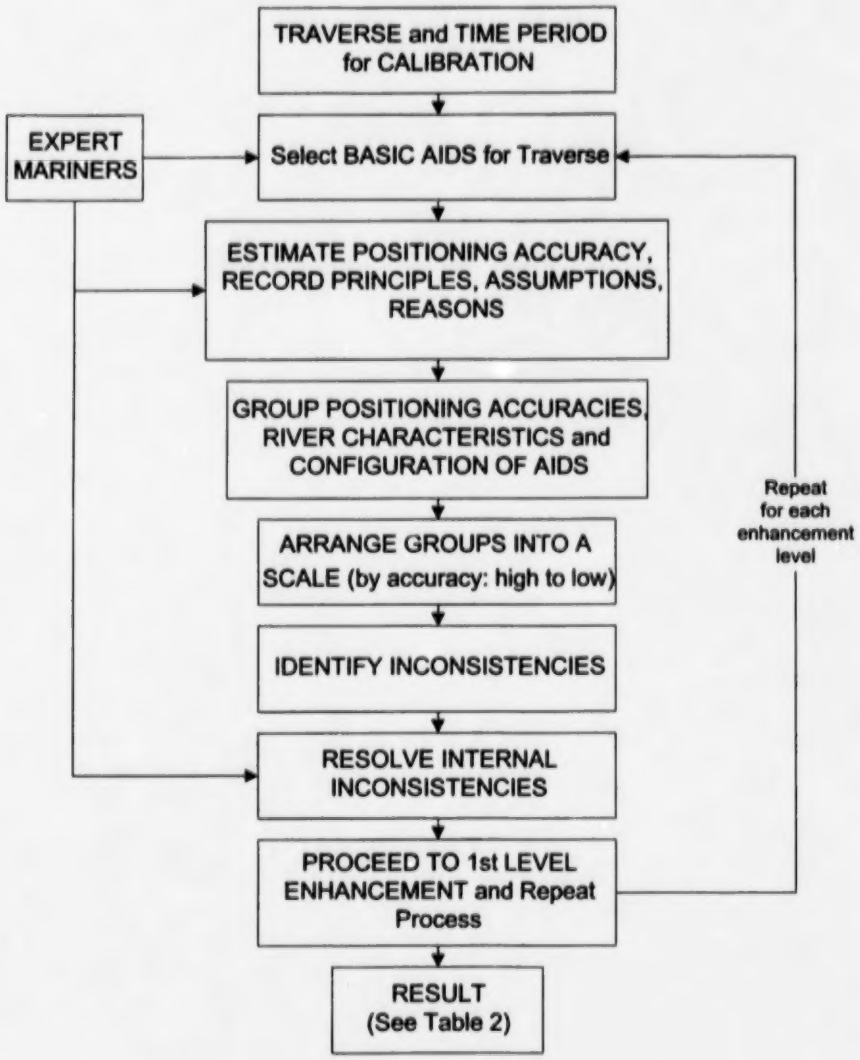

TRAVERSE and TIME PERIOD for CALIBRATION
EXPERT MARINERS
Select BASIC AIDS for Traverse
ESTIMATE POSITIONING ACCURACY, RECORD PRINCIPLES, ASSUMPTIONS, REASONS
GROUP POSITIONING ACCURACIES, RIVER CHARACTERISTICS and CONFIGURATION OF AIDS
ARRANGE GROUPS INTO A SCALE (by accuracy: high to low)
IDENTIFY INCONSISTENCIES
RESOLVE INTERNAL INCONSISTENCIES
PROCEED TO 1st LEVEL ENHANCEMENT and Repeat Process
RESULT (See Table 2)
Repeat for each enhancement level

**Figure 6. Development Process for Positioning Tables**

**Table 2. Example of Positioning Relationships**

| Radar range scale (nm) | Radar precision (m) | Good radar targets | Racons | Fixed aids | Good visual lead marks | Good visual turning marks | Ranges | Buoys | Primary navigation method | Confirmation navigation method | CW – positioning quality (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 71 | 4 | 2 | 0 | yes | yes | yes | 4 | R | R | 15 |
| 1.5 | 71 | 4 | 2 | 0 | yes | yes | no | 3 | V | R | 23 |
| 1.5 | 71 | 3 | 0 | 0 | yes | yes | no | 5 | V | R | 23 |
| 1.5 | 71 | 1 | 1 | 2 | yes | yes | yes | 9 | V | R | 15 |
| 3 | 83 | 2 | 1 | 1 | yes | yes | yes | 9 | V | R | 15 |
| 3 | 83 | 3 | 0 | 0 | yes | yes | yes | 4 | V | R | 15 |
| 3 | 83 | 3 | 1 | 2 | yes | yes | yes | 4 | V | R | 15 |
| 1.5 | 71 | 3 | 1 | 2 | yes | yes | yes | 5 | V | R | 15 |

Notes:

1. Several situations will have the same aids configurations and the same positioning accuracy.

2. Several situations will have different aids configurations but the same positioning accuracy because of different time periods, or because different combinations produce similar positioning quality.

# 6 Completion of the MSD Process: Overall LOS

At this point, for one traverse there may be up to ten sections, each with six time periods, and for each a value of (CW/MSD). It is necessary for some purposes to find a common measure of the LOS for the traverse. The following suggestions are presented.

## *6.1 Level of Service*

For CCG LOS or "design availability", a method of combining (CW/MSD) ratios and availability is proposed here that accounts for the frequency of occurrence of the time periods (winter, summer, good/poor visibility, etc.) and traffic volumes encountered.

At present, commercial LOS is met if aids to navigation are visible to establish position 75 percent of the time. To use the MSD tool to meet this LOS definition, simply determine whether CW/MSD ratios provide sufficient safety after entering into the MSD tool the minimum visibility threshold that occurs 75 percent of the time. Examples of conventional CCG LOS applied to commercial vessels in the study area can be found in Appendix D.

## *6.2 Risk*

The risk associated with each time period and section (i.e., a function of (CW/MSD)) is weighted by the relative number of vessels in each time period and the relative length of each section.

Risk along the waterway can then be determined by considering the magnitude of potential consequences. Risk receptors can be analysed by examining the maps provided in the Marine Navigation Safety System (MNSS), where Geographic Information System (GIS) and accident database functionality are available. The consequence analysis undertaken in this study is presented in Section 8.

The risk of alternative aids to navigation designs can be compared by examining the difference in the CW/MSD risk ratios. Any difference will result in a multiplier that can be applied as an adjustment to the accident rates calculated in MNSS. The accident analysis undertaken in this study is summarized in Section 7 and detailed in Appendix A.

Design availability might be more accurately determined by weighting the CW/MSD ratio for each time period (day, night, winter, summer, low visibility, good visibility) by the percentage occurrence of each time period, or, additionally, by the relative number of vessels in each time period. Thus, the "design availability" would be a function of an overall weighted CW/MSD.

If, for example, the chosen aids to navigation design was:

- "Unavailable" for one-way traffic, i.e., did not support, winter poor visibility navigation (annual occurrence 2 percent),
- "Available" for one-way traffic for 10 percent of the time, and
- "Available" for two-way traffic all other time periods,

then the annual LOS would be 88 percent.

# 7 Accident Analysis

## *7.1 Summary*

### 7.1.1 Scope

To conduct a risk assessment of selected marine accident scenarios in the St. Lawrence River and to validate results of the MSD tool, an accident analysis was required. This involved the computation of annual, summer and winter collision, grounding and striking frequencies for commercial vessels.

Depicted in Figure 7 are three study areas: the Saguenay approaches, the Traverse du Nord and Lac St. Pierre. Also indicated are MCTS calling-in-points (CIPs) within the study areas. The Maritime Safety Information System (MARSIS) database was used for accident analysis and the MCTS Data Archive and Distribution System (DADS) database was used for traffic analysis. Waterway areas defined in this study as "CIP areas" were used as the common geographical units for calculating accident rates.

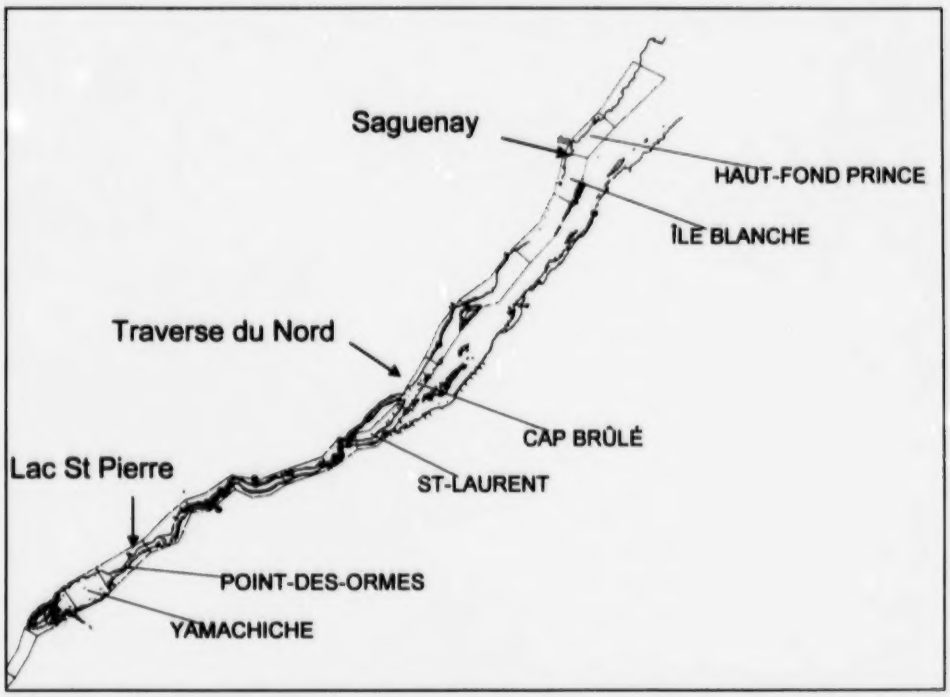



**Figure 7. Saguenay, Traverse du Nord and Lac St. Pierre Study Areas**

7.1.2 Accident rates

- Of the sample of 137 accidents analysed in the Laurentian Region, 30 percent were collisions and 60 percent were groundings (See Table 5),
- Most of the accidents involved bulk carriers and cargo vessels, followed by oil and petroleum product tankers (See Table 4),
- The highest accident rates occur in Grondines and Pointe-des-Ormes where one could expect an accident (probably a grounding by a bulk carrier or cargo vessel) with a "high damage degree" about once every five years (See Table 5), and
- Summer accident rates are significantly less than winter accident rates (See Table 6).

7.1.3 Validation of MSD method

- Comparisons of the MSD and CW data to accident data indicate the expected relationship between CW/MSD and accident rates for the areas studied (See Figure 9),
- Validation of the MSD method using accident data was limited by the available data. This is good for marine safety. It is unlikely that sufficient accident data will ever be available and it will be necessary to continue to incorporate expert opinion into the MSD method, and
- The MSD method results are correlated to existing practice and this, along with the positive reception from stakeholders, suggests that the MSD method provides a systematic and logical method for assessing safety requirements and the level of risk on the river.

## *7.2 Objective*

The objective of the accident analysis was to validate and confirm the approach used in MSD method for channel design. While there is over 20 years of data, the validation of the MSD method requires much more data to examine the details of the model, so the validation must be at some intermediate level that considers aggregated sections of the river and aggregated time periods. As indicated by the results, the accident analysis is sufficient to broadly confirm the method but the validity of the model details still depends on the careful elicitation of expert opinion. In addition, it will be seen that the data limitations preclude more extensive analysis of existing data.

To meet this objective the following tasks were required:

- develop the risk profile of the river, especially with respect to groundings, collisions, and strikings involving tankers, merchant and passenger vessels,

- obtain accident rates for specific sections of the river for comparison to the MSD results and validation of the MSD methodology, and

- focus on accidents related specifically to shiphandling and positioning in the river, related to the provision of aids to navigation.

## *7.3 Methodology*

### 7.3.1 Overview of approach

The purpose of comparing the CW/MSD values to accident rates was to validate the method with historical accident occurrences. A lower value of CW/MSD was expected to be associated with higher accident rates because it represents a waterway section with higher navigation risk. However, this examination was limited by the data sets; these included:

- only 137 accidents (non-mechanical failure, by through traffic only) occurred in the waterway between Escoumins and Montreal areas in 22½ years, and

- just over 100 CW/MSD estimates.

With a subset of only 137 accidents related to the value of aids to navigation and navigational aids, there was limited data to validate the MSD method which has dozens of parameters and is applied to hundreds of sections in the St. Lawrence River (see Figure 8). Even at the level of CIP areas, there are two CIP areas with no accidents and three with only one accident. Thus, the accuracy of the accident data is limited even before consideration of summer/winter and other factors.

The number of river sections for which MSD values have been estimated is limited and many of the estimates are still preliminary. They have been made in order to estimate parameters in the MSD method and to use expert opinion to formulate the model structure, especially for the "positioning" component of the MSD tool. Not all the aids configurations examined with the MSD tool were directly comparable. One direct comparison is provided in Table 3 where CW/MSD ratios less than one are indicated in bold type.

**Table 3. Comparison of the Bi–directional CW/MSD Ratios for Two Aids Configurations in Courbe Pointe du Lac**

| | | Channel width / MSD ratio | | |
|---|---|---|---|---|
| Section number | Section name | AASL Aids | Existing Aids | Change |
| 1 | A/C– C–63 | 1.40 | 1.40 | |
| 2 | Pont Laviolette | **0.77** | **0.77** | |
| 3 | Pointe–des–Ormes – St. François | 1.20 | 1.60 | |
| 4 | Courbe Nicolet | 1.28 | 1.28 | |
| 5 | Courbe Pointe du Lac | 1.06 | 1.06 | |
| 6 | Course Pointe du Lac | **0.89** | 1.23 | **–28%** |
| 7 | Course Pointe du Lac | **0.94** | 1.07 | **–12%** |
| 8 | A/C S–54 | **0.95** | **0.95** | |

Conditions: summer, one nmi visibility, two container vessels

The limited accident data will not change, but it is expected that as the MSD method is used, there will eventually be estimates for most parts of the river for most conditions. All MSD worksheets prepared for the study areas are included in Appendix B.

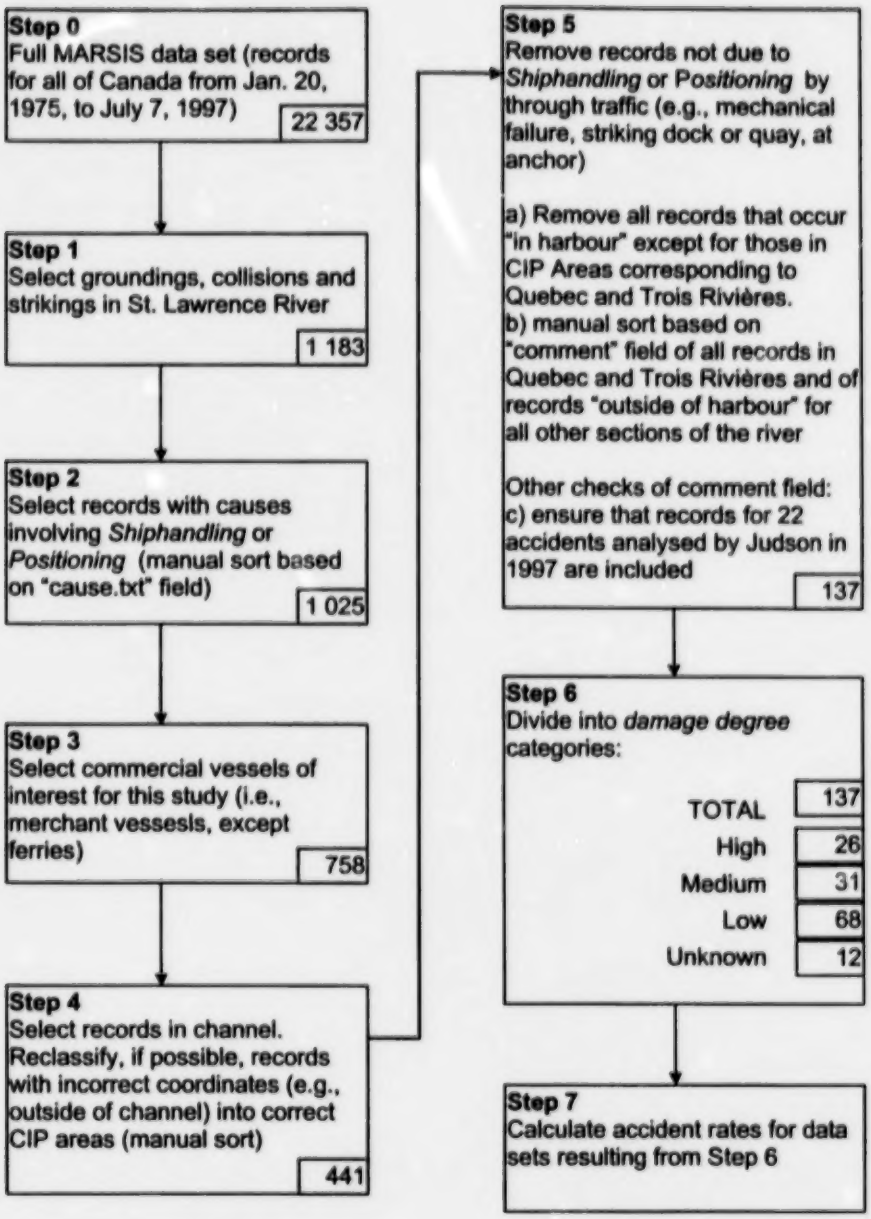

Step 0
Full MARSIS data set (records for all of Canada from Jan. 20, 1975, to July 7, 1997)
22 357
Step 1
Select groundings, collisions and strikings in St. Lawrence River
1 183
Step 2
Select records with causes involving *Shiphandling* or *Positioning* (manual sort based on "cause.txt" field)
1 025
Step 3
Select commercial vessels of interest for this study (i.e., merchant vessesls, except ferries)
758
Step 4
Select records in channel. Reclassify, if possible, records with incorrect coordinates (e.g., outside of channel) into correct CIP areas (manual sort)
441
Step 5
Remove records not due to *Shiphandling* or *Positioning* by through traffic (e.g., mechanical failure, striking dock or quay, at anchor)
a) Remove all records that occur "in harbour" except for those in CIP Areas corresponding to Quebec and Trois Rivières.
b) manual sort based on "comment" field of all records in Quebec and Trois Rivières and of records "outside of harbour" for all other sections of the river
Other checks of comment field:
c) ensure that records for 22 accidents analysed by Judson in 1997 are included
137
Step 6
Divide into *damage degree* categories:
TOTAL 137
High 26
Medium 31
Low 68
Unknown 12
Step 7
Calculate accident rates for data sets resulting from Step 6

**Figure 8. Overview of Data Selection Steps (revised October 22, 1998)**

Note: The number of accident records resulting from each step is shown in the box in bottom right corner.

### *7.4 Results*

Table 4 shows the total number of commercial vessel accidents in the Laurentian Region (using exiting MARSIS and MCTS boundaries) that involved shiphandling or positioning difficulties, between 1975 and 1997. Records from this intermediary table meeting further criteria were ultimately grouped as a set of collisions, groundings and strikings:

- Of commercial traffic (in bold type), except ferries,
- In a navigation channel and not involved in an arrival or departure to a dock or anchorage, and
- Where the accident was probably due to an error in shiphandling or positioning.

Most of the accidents involved bulk carriers and cargo vessels followed by oil and petroleum product tankers.

**Table 4. Selected Commercial Vessels of Interest by Accident Type**

| Vessel Type | Selected | Collision | Grounding | Striking | Grand Total |
|---|---|---|---|---|---|
| **Bulk** | **X** | **128** | **110** | **136** | **374** |
| **Cargo** | **X** | **63** | **43** | **79** | **185** |
| **Chemical_tanker** | **X** | **6** | **5** | **7** | **18** |
| **Container** | **X** | **7** | **6** | **11** | **24** |
| Ferry | | 13 | 6 | 11 | 30 |
| **Fishing** | **X** | **3** | **3** | **1** | **7** |
| Government | | 23 | 18 | 26 | 67 |
| **LPG_LNG_carrier** | **X** | **0** | **1** | **0** | **1** |
| Other_over_20m | | 9 | 12 | 7 | 28 |
| Other_under_20m | | 24 | 2 | 7 | 33 |
| **Passenger** | **X** | **12** | **11** | **21** | **44** |
| **Tanker_over_50000 DWT** | **X** | **0** | **0** | **2** | **2** |
| **Tanker_under_50000 DWT** | **X** | **40** | **28** | **35** | **103** |
| Tug | | 46 | 32 | 27 | 105 |
| Tug with oil barge | | 2 | 2 | 0 | 4 |
| Grand total | | 376 | 279 | 370 | 1025 |
| **Total** | | **259** | **207** | **292** | **758** |

Table 5 provides estimates of accident rates for the St. Lawrence River. After further refining of the data set using the process outlined in Figure 8, accident rates were calculated for 19 areas along the river centred on the position of a MCTS CIP. This type of reference position was chosen because it is a consistent point of vessel traffic data capture for DADS. An explanation of the process used to calculate these accident rates is provided at the bottom of Table 5. Other details and definitions are provided in Appendix A.

Table 5 indicates that 30 percent of accidents are collisions and 60 percent are groundings. The highest accident rates occur in Grondines and Pointe-des-Ormes, where one could expect an accident (probably a grounding) with a "high damage degree" about once every five years. For Grondines, this translates to 0.35 accidents every 100 000 nmi travelled in this section of the river.

## Table 5. Annual Accident Rates by CIP Area and Damage Degree

| CIP Area | | | | | Total | | Breakdown by Damage Degree *** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual | Length | Traffic nmi | Accident | Annual | High | | Medium | | Low | |
| # | Name | Traffic Count (95/96)** | (nmi, rounded) | (Count x nmi actual) | (Count per 22.5 years) | Accident RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* |
| 5 | ESCOUMINS | 4 857 | 17 | 81 112 | 3 | 0.16 | 0 | 0.00 | 0 | 0.00 | 3 | 0.16 |
| 6 | HAUT–FOND PRINCE | 4 928 | 13 | 65 542 | 2 | 0.14 | 2 | 0.14 | 0 | 0.00 | 0 | 0.00 |
| 7 | ILE BLANCHE | 4 871 | 11 | 55 042 | 3 | 0.24 | 0 | 0.00 | 2 | 0.16 | 1 | 0.08 |
| 0 | CAP AU SAUMON | 4 849 | 19 | 90 676 | 1 | 0.05 | 1 | 0.05 | 0 | 0.00 | 0 | 0.00 |
| 8 | CAP–AUX–OIES | 4 876 | 21 | 102 396 | 1 | 0.04 | 0 | 0.00 | 0 | 0.00 | 1 | 0.04 |
| 9 | GRAND–POINT | 4 366 | 16 | 77 856 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 10 | CAP BRULE | 4 869 | 14 | 69 627 | 4 | 0.26 | 2 | 0.13 | 0 | 0.00 | 2 | 0.13 |
| 11 | ST. LAURENT | 4 923 | 16 | 78 768 | 1 | 0.06 | 0 | 0.00 | 0 | 0.00 | 1 | 0.06 |
| 13 | QUEBEC | 4 488 | 10 | 44 431 | 23 | **2.30** | 1 | 0.10 | 7 | **0.70** | 10 | **1.00** |
| 14 | ST. AUGUSTIN | 4 535 | 12 | 53 967 | 8 | 0.66 | 4 | **0.33** | 3 | 0.25 | 1 | 0.08 |
| 15 | DONNACONA | 4 535 | 14 | 62 130 | 6 | 0.43 | 0 | 0.00 | 2 | 0.14 | 3 | 0.21 |
| 16 | GRONDINES | 4 538 | 14 | 61 263 | 17 | **1.23** | 5 | **0.36** | 3 | 0.22 | 8 | **0.58** |
| 17 | BATISCAN | 4 557 | 16 | 72 912 | 13 | 0.79 | 2 | 0.12 | 1 | 0.06 | 10 | **0.61** |
| 19 | POINTE–DES–ORMES | 4 321 | 15 | 63 087 | 23 | **1.62** | 5 | **0.35** | 7 | **0.49** | 9 | **0.63** |
| 20 | YAMACHICHE | 4 354 | 10 | 44 411 | 9 | 0.90 | 2 | 0.20 | 4 | **0.40** | 3 | 0.30 |
| 21 | ILE DES BARQUES | 4 357 | 14 | 62 305 | 11 | 0.78 | 0 | 0.00 | 2 | 0.14 | 7 | 0.50 |
| 22 | TRACY | 4 080 | 12 | 50 592 | 4 | 0.35 | 0 | 0.00 | 0 | 0.00 | 4 | 0.35 |
| 24 | CAP ST. MICHEL | 4 179 | 11 | 45 969 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 25 | MONTREAL EST | 4 424 | 9 | 38 046 | 8 | 0.93 | 2 | 0.23 | 0 | 0.00 | 5 | **0.58** |
| Grand Total | | | | 1 220 132 | 137 | 0.50 | 26 | | 31 | | 68 | |
| CASUALTY TYPE | | | | | | | | | | | | |
| Collisions | | | | | 41 | | 4 | | 18 | | 12 | |
| Groundings | | | | | 80 | | 21 | | 6 | | 49 | |
| Strikings | | | | | 16 | | 1 | | 7 | | 7 | |
| Mean | | | | | | 0.58 | | 0.11 | | 0.14 | | 0.28 |
| Standard Deviation | | | | | | 0.62 | | 0.13 | | 0.20 | | 0.29 |
| Mean + 1 SD | | | | | | 1.20 | | 0.24 | | 0.34 | | 0.57 |

*e.g., for ESCOUMINS: 4857 x 16.7 =81 112 vessel miles per year. 3/22.5 = .13 accidents per year or per 81 112 nmi, or .16 accidents per 100 000 nmi traveled. Accident data from 1/20/75 to 7/7/97.

** Includes all merchant vessels except for ferries for one year (95–96).

*** For 9% of the set of 137 records, damage degree is "unknown". These records are included in the grand total only.

The CIP areas with rates more than 1 SD above the mean are shown in bold typeface.

Table 6 and Figure 9 show that even with a small number of sample points, it is possible to see that higher accident rates equate to lower values of CW/MSD.

**Table 6. Comparison of CW/MSD Values and CIP Accident Rates (Bi–directional*)**

| CIP Area | CIP Number | CIP Median CW/MSD | CIP Accident Rate (Annual) | CIP Accident Rate (Summer) |
|---|---|---|---|---|
| Haut–fond Prince | 6 | 3.0 | 0.14 | 0.07 |
| île Blanche | 7 | 3.55 | 0.24 | 0 |
| Cap Brûlé | 10 | 1.24 | 0.26 | 0 |
| St. Laurent | 11 | 1.64 | 0.06 | 0 |
| Pointe–des–Ormes | 19 | 1.21 | 1.62 | 0.56 |
| Yamachiche | 20 | 1.06 | 0.90 | .30 |

* For CIPs 6 and 7 the bi-directional CW/MSD was estimated from the unidirectional values by a factor of .54 (average for sections 10-11) to make results comparable.

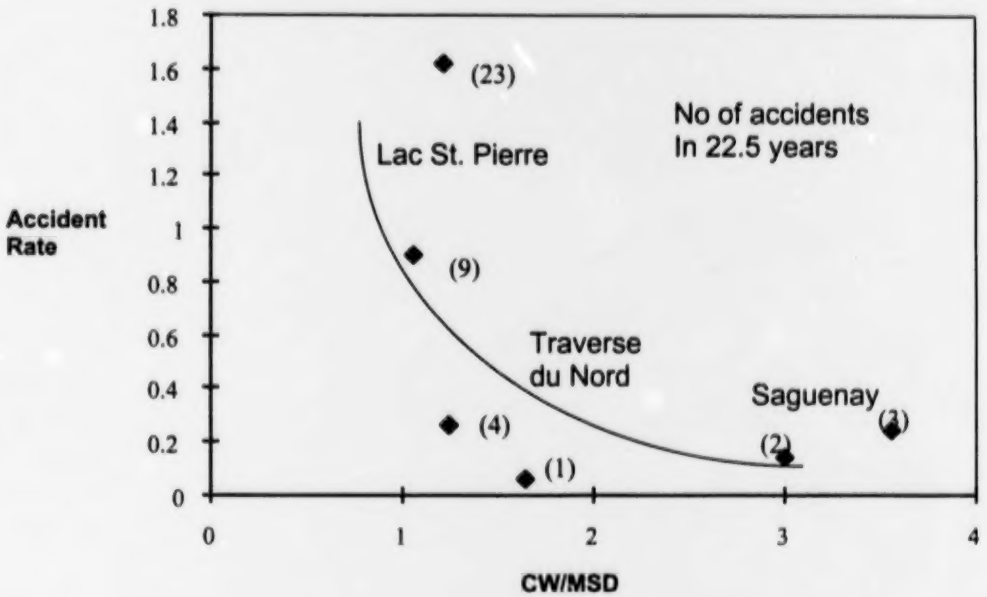



**Figure 9. CIP Accident Rate versus CIP Median CW/MSD Ratio**

However, comparing the CW/MSD ratio to historical accident locations is more difficult. Figure 10 shows grounding locations and CW/MSD values for a summer scenario in Lac St. Pierre (CW/MSD values are indicated as "DMS").

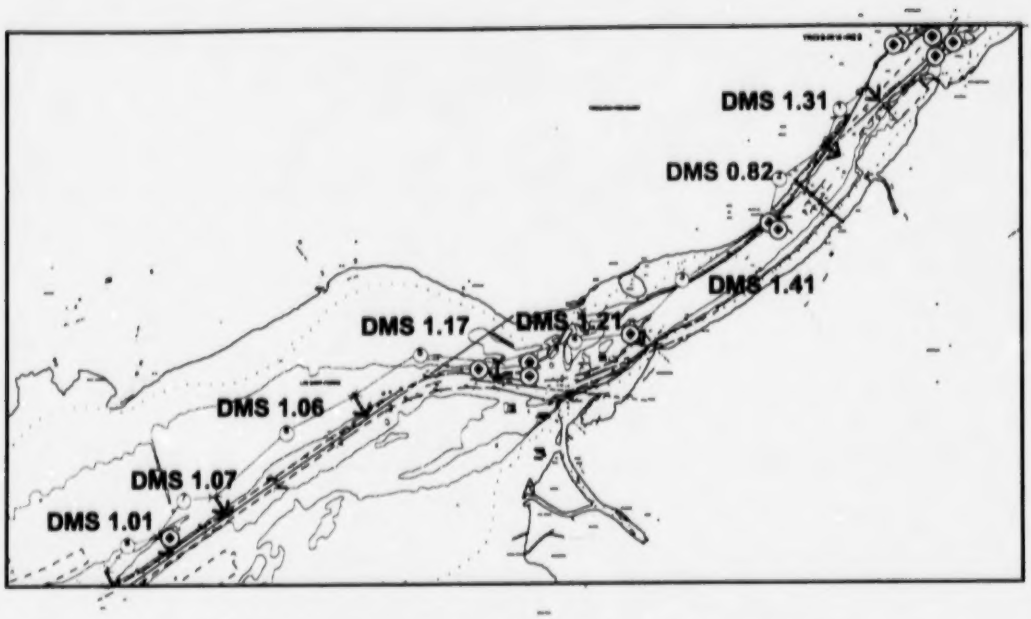



**Figure 10. Grounding Positions and CW/MSD**

While there is a general relationship between CW/MSD and observed accident rates, there may not be a one-to-one correspondence between historical accident location and grounding risk for several reasons:

- The MSD tool is evolving to better reflect MBP, which keeps 99.9% of vessels safe; but, some accidents have a random component that no regulation or aids to navigation infrastructure can change,
- The measurement of channel width is less exact in turns and open water, and
- MSD includes many primary factors for safe navigation – but there are additional secondary causes of accidents.

Some of these accident causes considered but not automated in MSD include:

- Additional impacts of turns: heel squat is part of "safety margin" which is applied to turns and straight sections,
- The effects of ports and port traffic on workload,
- Accidents due to changes in pilots, both prior to and after the changeover point,
- Additional impacts of bridges,

- Accidents that are initiated at mile (m) resulting in a grounding at (m)+(x) nmi so there is a distance lag between the source of the accident and the location of the accident. For example, some pilots indicated that they took extra care in the difficult sections of the river and might sometimes "let down their guard" after the difficult section. This is a type of reverse feedback effect, and

- Location of higher incidence of fatigue.

The data limitations preclude the identification of these causes from accident data. However, it may be possible to obtain evidence to support the future inclusion of some of these and other secondary factors in addition to the primary causes already incorporated in the MSD method. Some sources of evidence might be from the observation of "close calls" or the systematic collection of reliable expert opinion with test of internal consistency.

# 8 Consequence Analysis

The consequence analysis component of the project addressed the worst plausible outcomes from a marine shipping scenario on the St. Lawrence River. The 1996 DADS database was reviewed to determine the commodities shipped and the frequency of shipment. An initial examination of the data revealed that the list of hazardous products carried included many different petrochemical products out of the 71 different category groupings. Bunker C heavy fuel oil was number 11 on the list (ordered by trip frequency) with 92 trips and gasoline was number 12 with 87 trips. These two commodities were retained for study under an oil spill scenario and a fire/explosion scenario, both within the Lac St. Pierre segment of the river.

## *8.1 Oilspill Modelling*

This scenario assumes a product tanker, carrying bunker C heavy fuel oil, collides with another vessel in the Pointe-du-Lac turn of Lac St. Pierre where historically, a significant number of marine incidents have occurred. One hold in the 3x6 configuration is ruptured at the waterline, setting up a 24-hour spill event. The 5 000 $m^3$ tank is initially 90 percent full and 30 percent of the contents or 1 350 $m^3$ is spilled into the river (see MIL Systems report # 1736-0011-01 for detail (5)).

To facilitate the consequence analysis, the oil spill model "Oilmap" was deployed to investigate the probability of shoreline oiling and to examine the fates and amount of oil contacting risk receptors in the study area. Hydrodynamic modelling of the St. Lawrence River included:

- Mean river flow by season, and
- Actual currents in the river influenced by tidal effects, seasonal observations, tributaries and bathymetry.

Significant sources of data included the Canadian Hydrographic Services current atlas for the river and electronic chart vector data supplied by Nautical Data International.

Wind records were also assembled from Environment Canada's Nicolet station for a five-year period. Hourly records for the period 1993-98 were properly formatted in terms of wind speed and direction in preparation for use by the consequence model.

The consequence analysis was based on a series of three stochastic studies for the months of February, May and September to investigate seasonal effects. In

this mode of operation, 100 trials per month were simulated where spill start times were randomly selected, constrained by the month studied and 48 hours of wind data was ingested for each trial. Hence, a spill trajectory for each trial was computed and the spillets contacting the shore are recorded. The ensemble of the 100 trajectories was then analysed to produce the probability of shoreline oiling. Overall river flow rates were selected by season prior to each stochastic study. The oiling probability results were found to be relatively insensitive to the seasonal flow rate changes.

The scenario results produced shoreline impact probability maps by grid cells of 0.84 km length in ranges of 10 percent impact probability. A map for each of the months studied can be found in figures 11–13.

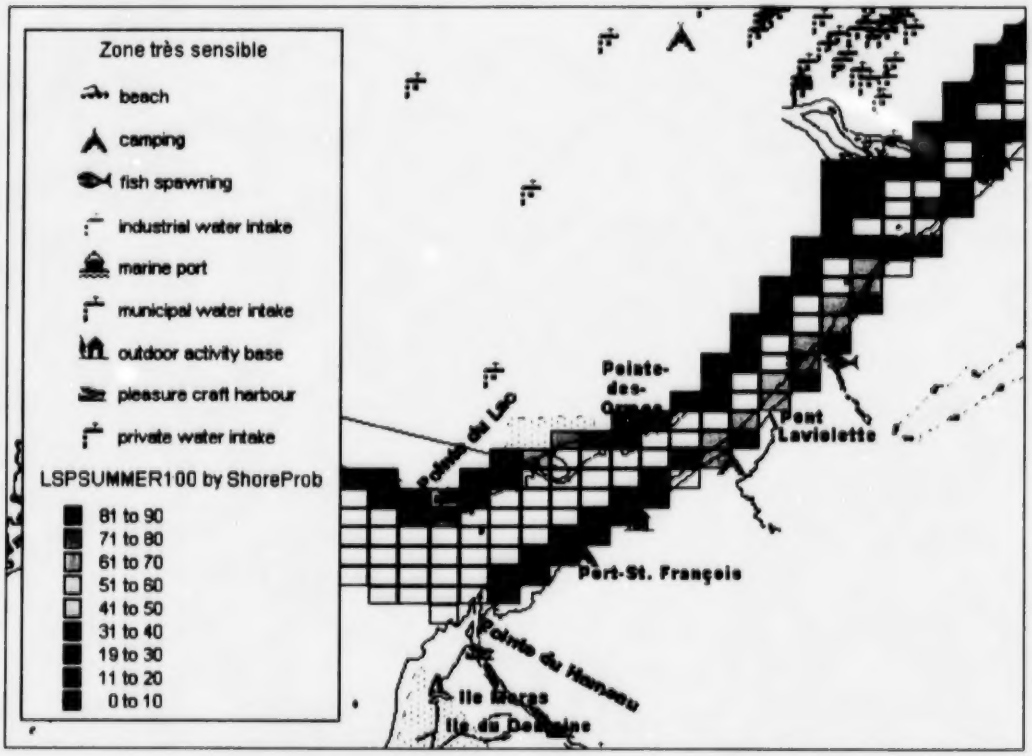



**Figure 11. Shoreline Impacts – September Winds**

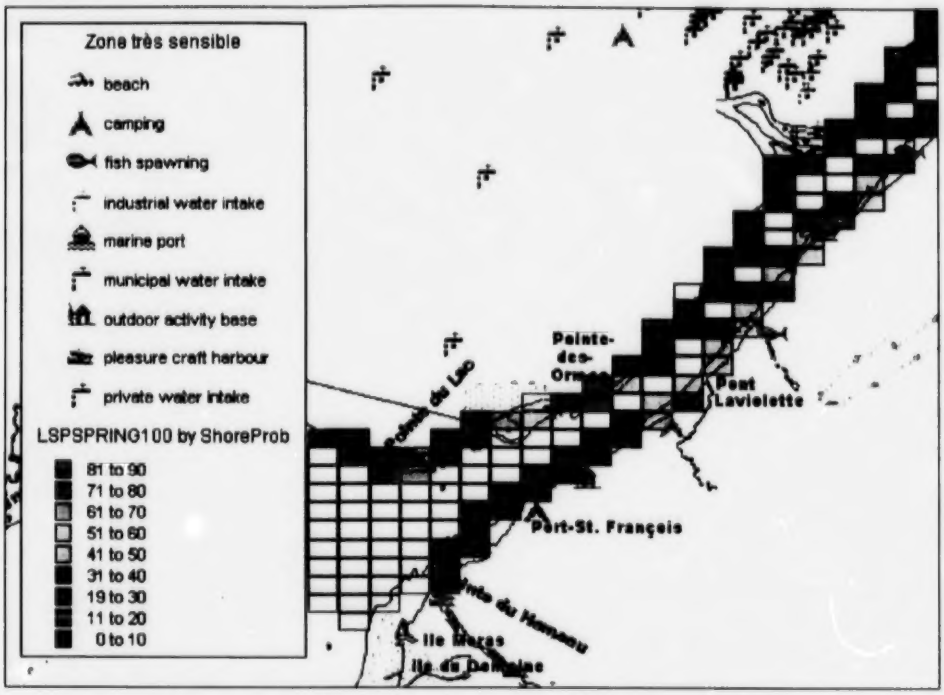



**Figure 12. Shoreline Impacts – February Winds**

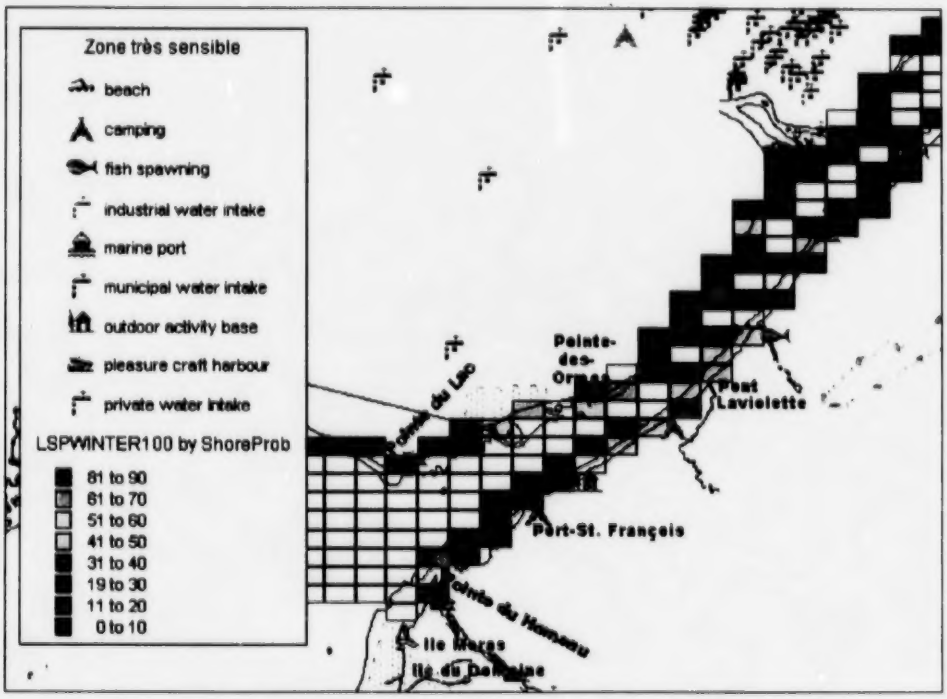



**Figure 13. Shoreline Impacts – May Winds**

8.1.1 Oil spill results

For each of the three months where stochastic trials were run, a specific oiling trend was noted. The higher probability zone extends from the Pointe-du-Lac turn to Trois Rivières/Cap-de-la-Madeleine, where the oiling probability exceeds 20 percent in all cases. The total shoreline distance is approximately 16 km on either side of the river. Other trends common to the three stochastic are listed in Table 7.

**Table 7. Probability of Shoreline Oiling by Shoreline Resource Receptor**

| Shoreline Resource | Percentage Probability Hit |
|---|---|
| Pointe–du–Lac village (outdoor activity base, marina) | 80% |
| Ile–aux–Sternes ecological reserve | 60–70% |
| Pointe–des–Ormes | 85% |
| Industrial water intake (Kruger Pulp & Paper) | 15–25% |
| Port infrastructure – Trois Rivières | 40% |
| Marina – Trois Rivières | 30% |
| Camp site – Port St. François | 25% |
| Outdoor activity base – Port St. François | 40% |
| Campsite – Becancour | 40% |
| Municipal water intake – Becancour | 50% |
| Fish spawning – Rivière Godefroy | 50% |
| Marina – Becancour | 55% |
| Fish spawning – St. Angèle de Laval | 55% |
| Fish spawning – Trois Rivières | 25% |

Financial costs of oil spill events depend on the amount and type of product spilled, the location and timing of the spill event, the sensitive areas affected, the weather during clean-up and the techniques deployed. Ninety percent and above of the total cost of a spill can be attributed to the shoreline clean-up procedures. The *Oil Spill Intelligence Report* (6) suggests an upper boundary for on-shore clean-up at $150-$300 K per tonne recovered. Others have suggested US$19 000 (7) and CDN$22 000 (8) are more typical figures.

Proximity of the spill to populated areas where beaches, marinas and cultural land use are prevalent will drive the cost to the high end of the upper boundary. The same is true for viscous crudes and heavy fuel oils, where persistence of these hydrocarbons is higher than for lighter products. The largest expense in shoreline clean-up is for disposal of oily debris.

Following the impact of the 1967 Torrey Canyon spill, the International Maritime Organization (IMO) sponsored a international legal conference on maritime

pollution damage to establish the Civil Liability Convention (CLC) where the polluter pays principle applies. The signing parties to the CLC agreed that the ship owner (at the time of a pollution incident) is liable for damages caused unless the incident is caused by:

- An act of war,
- An exceptional natural phenomenon,
- The malicious act of a third party, or
- The negligence of a government authority in maintaining navigational aids.

Note that even so-called minor spills could require a complex response operation, triggering an incident command system. The various coordinators, managers and trained personnel wearing protective gear (in need of decontamination prior to every meal), damage assessment teams and lawyers contribute to the costs, which escalate according to their respective per diem charge-out rates.

The Courbe Pointe-du-Lac spill costs must take into account the following categories:

- Tanker costs: value of lost oil, tanker repair costs and lost business opportunity or chartering costs,
- Incident report filing costs: provincial, national, insurer, fund,
- Initial clean-up costs: on-scene coordinator fees, response organization fees, command centre fees,
- Mechanical containment and recovery costs: booms, equipment, clothing, logistics, disposal, permits,
- Manual shoreline clean-up costs: equipment, clothing, logistics, disposal, permits,
- Additional costs: worker compensation claims, damage costs due to clean-up work, media relations,
- Restoration costs: replanting wetland plant species, restocking fish, expert evaluation of spill damage,
- Settlement costs: legal fees, civil damages,

- Industrial and municipal water intake damages, and
- Business losses: outdoor activity bases, marinas, campsites, etc.

### 8.1.2 Actual cost estimates

The St. Lawrence River spill cost model developed in the Arctic Tanker Risk Analysis program was adapted for this project.

Considering the cost categories listed above, the total cost of a 1 350 $m^3$ spill would exceed $22.2 million (see Figure 14). Figure 14 provides details of the range of costs expected to result from an oil spill. Details of the source for these estimates are in the report TP12325E (8), pp. 47-68; however, some specific cost estimates for the Courbe Pointe-du-Lac are provided in Figures 14–15.

**Scenario** St. Lawrence River (Pointe-du-lac turn of Lac Saint-Pierre), collision, 1 hold penetrated

| | |
|---|---|
| 1 | Accident type Collision/striking = 1; Grounding = 2) |
| 2 | Distance from shore (Far = 1, near = 2) |
| 1 | Clean-up sensitivity (High = 1; medium = 2; low = 3) |
| 1 | Civil damages sensitivity (High = 1; medium = 2; low = 3) |
| 1 | Natural resource damages & fines sensitivity (High = 1; medium = 2; low = 3) |
| 0.2 | Waveheight (metres) |
| | Ice concentration (tenths) |
| 2.5 | Across track current (knots) |
| 0 | Evaporation (Default: Ice concentration > zero = 30%, Ice conc. zero = 40 %) |
| 4500 | Cargo in holed tank (tonnes) |
| 25 | Primary release % ( if grounding, default = 20%, collision, default = 100%) |
| | Accidental burn (tonnes) |

**Countermeasures**

| | |
|---|---|
| 100 | On-board transfer capability in tonnes/hr |
| 10000 | Capability of Off-loading tanker (estimate of tonnes before adjusting for release or transfer on board) |
| 24 | Off-loading barge/tanker/vessel ETA in hours |
| 6 | Boom and skimmer deployed within___hours? |
| 70 | Percentage of cargo escaped from boom (Default: = 10% if currents < 1 knot and 50% if >= 1 knot) |
| 2 | Dispersant approval (affirmative = 1, negative = 2; Default = 1 if Distance is far and Waveheight < 1.1 metre) |
| 2 | In-situ burning approval (affirmative = 1; negative = 2; Default = 1 if Ice concentration >5.9 tenths) |
| | Effectivess of in-situ burning in >5.9 tenths ice or in fireboom (Default = 80%) |
| | Days of effective burning (Default = 3 days) |
| | Burn rate per hour (Default = 100 tonnes per hour) |
| | Effectiveness of recovery of oil at sea (Default = 3.8%) |
| | Percentage of stranded oil attacked (Default = 100% if nearshore, nil if far from shore) |
| | Effectiveness of recovery ashore (Default = 47%) |

**Costs**

| | |
|---|---|
| 26 | Cargo cost per barrel CAN$ |
| 6500 | Vessel opportunity cost per day CAN$ (profit loss) |
| 60 | Days out of service |
| 5000000 | Vessel damage cost |
| | Cost per tonne recovered by self-help booming (Default = $75) |
| | Cost per tonne recovered by off-loading (unknown) |
| | Cost per tonne treated by dispersant from C130 (Default = $347 @ 1:15) |
| | Cost per tonne burned in-situ (Default = $13) |
| | Cost per tonne recovered by mechanical recovery at sea (Default = $9,991) |
| | Cost per tonne recovered ashore (Default sensitivity: high = $22,000; medium = $6,000; low = $1000) |
| | Civil damages (Default sensitivity: high = $1.7 million; medium = $1 million; low = $5600) |
| | Natural resource damages & fines (Default sensitivity: high = $1 million; medium = $100,000; low = $10,000) |

**Figure 14. Spill Cost Model Parameters**

| | | | Oil (tonnes) | Clean-up cost (C$) | Civil damages (C$) | Natural resource damages & fines (C$) | Own-ship costs (C$) | Cost % |
|---|---|---|---|---|---|---|---|---|
| **Cargo in hold(s)** | | | 4500 | | | | | |
| Primary release | | | 1110 | | | | | |
| Secondary release (minimum) | | | 240 | | | | | |
| Accidental burn | | | 0 | | | | | |
| **Total oil released** | | | 1350 | | | | | |
| **Own damage** | | | | | | | | |
| Cargo cost | | | | | | | $220,730 | |
| Opportunity Cost | | | | | | | $390,000 | |
| Vessel Damage | | | | | | | $5,000,000 | 25.2% |
| **Self-help countermeasures** | | | | | | | | |
| On-board transfer | | | 2400 | | | | | |
| Off-loaded | | | 750 | | | | | |
| Recovery by boom | $75 | /tonne recovered | 0 | $0 | | | | |
| **Escaped oil** | | | 1350 | | | | | 0.0% |
| **Clean-up at sea** | | | | | | | | |
| C130 with ADDS and dispersant @1.15 | | | | | | | | |
| | $347 | /tonne treated | 0 | $0 | | | | |
| Burned in-situ | $13 | /tonne burned | 0 | $0 | | | | |
| Mech. recovery | $9,991 | /tonne recovered | 51 | $512,424 | | | | |
| Evaporation | | | 0 | | | | | 2.3% |
| **Consequence mitigation** | | | | | | | | |
| **Oil impacting on the coastal zone** | | | 1298 | | | | | |
| **Civil damages** | $1,700,000 | | | | $1,700,000 | | | |
| **Natural resource damages/fines** | | | | | | | | |
| | $1,000,000 | | | | | $1,000,000 | | |
| Stranded oil attacked | | | 1298 | | | | | |
| **Shore clean-up, protection and disposal** | | | | | | | | |
| | $22,000 | /tonne recovered | 610 | $13,425,574 | | | | |
| **Oil left for natural recovery or bioremediation** | | | 688 | | | | | 72.5% |
| **Sub-total Costs** | | | | $13,937,998 | $1,700,000 | $1,000,000 | $5,610,730 | 100.0% |
| **Total cost** | | $22,248,728 | | | | | | |

**Figure 15. Spill Cost Model Output**

*Municipal and industrial water intake clean–up costs*

Municipal water intake clean-up costs were estimated at $50 000 per system. Industrial water intake clean-up costs were given a much less certain estimate of five times the municipal costs, or $250 000. The Municipality of Becancour was consulted to provide the following assumptions and breakdown of costs to clean up an oil-fouled municipal water intake:

Assumptions:

- Insufficient advance warning to shut down system prior to bunker C trajectory arrival,
- On-site staff (24 hr) gets a visual on oiling of the internal basin, proceeds with shut down, and
- Quick response requirement: outside contractors at x2 cost factor.

Municipal clean-up cost:

- Water intake $2 000,
- Basin $5 000,
- Conduits $2 000,
- Pumps x4 $20 000,
- Decanters, flash mix, etc. $20 000, and
- Total cost is $50 000.

Industrial clean-up cost:

- Industrial water intake clean-up should be about five times the municipal clean-up costing given that the volume of water handled is 12 times that of the municipal facility – this also takes into account the lower complexity of the water treatment system for industrial use.

The study zone did not extend downstream to include the Becancour industrial intake, but it did include the Kruger industrial intake. Therefore, a $250 000 cost was applied to clean up the water intakes for this facility.

*Small marina business loss and vessel clean–up costs*

A small marina with bar/restaurant would probably suffer a $20 000 loss per week. The vessel owners would also incur clean-up costs for their yachts this – could reach $14 000 assuming a small marina has an average of 20 yachts in the water. A boat hauling company (9) was consulted who provided cost information. Yacht clean-up costs were estimated at $700 per vessel using an average boat length of 9.5 m. This includes: boat lifting, round trip hauling of 300 km, clean-up and disposal of oily wastes.

In summary, infrastructure clean-up and civil damage costs would be at least $342 000. This includes: three marinas, a municipal water intake and an industrial water intake. Business loss for the three marinas would total about $60 000 for one week. Other losses such as tourism revenue and recreation impacts have not been valuated and would likely increase the $342 000 to the highest category of civil damages cost of $1 700 000 estimated for an area of high sensitivity in the spill cost model. Clean-up of the river and the shoreline environment would exceed $8 million; fines for environmental damage could reach the maximum $1 million; vessel damage, cargo and business loss could exceed $5 million. This brings the cost of a single 1 350 $m^3$ oil spill to $22.2 million.

### *8.2 Gasoline Fire/Explosion Modelling*

This scenario assumes a product tanker carrying gasoline collides with another vessel near the port of Trois Rivières while on course Pointe-des-Ormes. This sets up a 1 350 $m^3$ release event which was modelled using the PHAST consequence modelling package.

When considering the potential hazard for fire or explosion in tankers, the initiation mechanism is important. When petroleum is ignited, the gas emanating from the liquid burns as a visible flame. A specific proportion of air mixing must take place for burning to occur. The limiting proportions, expressed as a percentage by volume of petroleum gas in air are known as the *upper and lower flammability limits* (UFL, LFL). The gas mixtures encountered in normal tanker practice can range from 1 percent gas by volume in air (LFL) to 10 percent gas by volume in air (UFL). To control the risk of fire/explosion on a tanker, ignition sources and flammable atmospheres must not be present at the same place and time.

Gasoline is transported as a liquid in product tankers and is classified as a flammable liquid with an LFL of 1.4 percent and a UFL of 7.6 percent at 20°C. It is moderately toxic by inhalation, ingestion and contact.

### 8.2.1 Scenario modelling

Three wind speeds were selected from Environment Canada records for the analysis. These included: wind speeds of 1.5 m/s with Pasquill atmospheric stability *F*, 5.6 m/s with stability *A* and 7.2m/s also with stability *A*. Stability *A* is very unstable while *F* is a very stable atmosphere.

Given the nature of the assumed collision, a catastrophic rupture would lead to an instantaneous release as the worst plausible event. A release on fresh water would result. The chemical properties of the gasoline product were specified in the mixture database including temperatures and pressures of interest.

The model initially computes discharging of the liquid cargo and the results are displayed for the possible outcomes for the mixture under study. For gasoline, three main outcomes are possible: a pool fire, a flash fire and an explosion. Each scenario produced an impact zone that would include industrial facilities and port infrastructure within the port of Trois Rivières.

### 8.2.2 Fire/explosion results

*Flash Fire Flame Envelope*

The worst plausible case arises from the *F* stability, 1.5 m/s case. Flash fires are lethal to all inside the flame envelope. At the LFL specified for gasoline, the radius of the envelope is approximately 500 m and at 0.5 LFL it extends beyond 600 m, as depicted in Figure 16. The impact zone would include industrial facilities and port infrastructure within the port of Trois Rivières.

*Radiation Radii for Pool Fire*

Three heat radiation levels are specified:

- 4 kW/sq m: 20 seconds of exposure will reach the pain threshold and second degree burns (skin blistering) are likely,
- 12.5 kW/sq m: 4 seconds to pain threshold, and
- 37.5 kW/sq m: causing equipment damage and is lethal.

The results are not particularly sensitive to weather conditions as wind only affects tilt angle of the radiation zone above the pool fire.

Figure 17 shows the 37.5 kW zone extending to approximately 200 m and the 4 kW zone to 350 m. The 200 m zone would barely extend to the shoreline in this case. The impact zone would also include industrial facilities and port infrastructure within the port of Trois Rivières.

*Late Ignition Explosion Overpressure*

The 1.5 m/s F stability case is again the worst plausible situation of the three weather cases. Figure 18 depicts locations for the most severe late ignition explosion overpressures (shock waves). At .21 bars, steel frame buildings can be distorted and severed from their foundations. An ignition source must be present for the vapour cloud explosion to occur. The impact zone would include industrial facilities as well as port infrastructure.

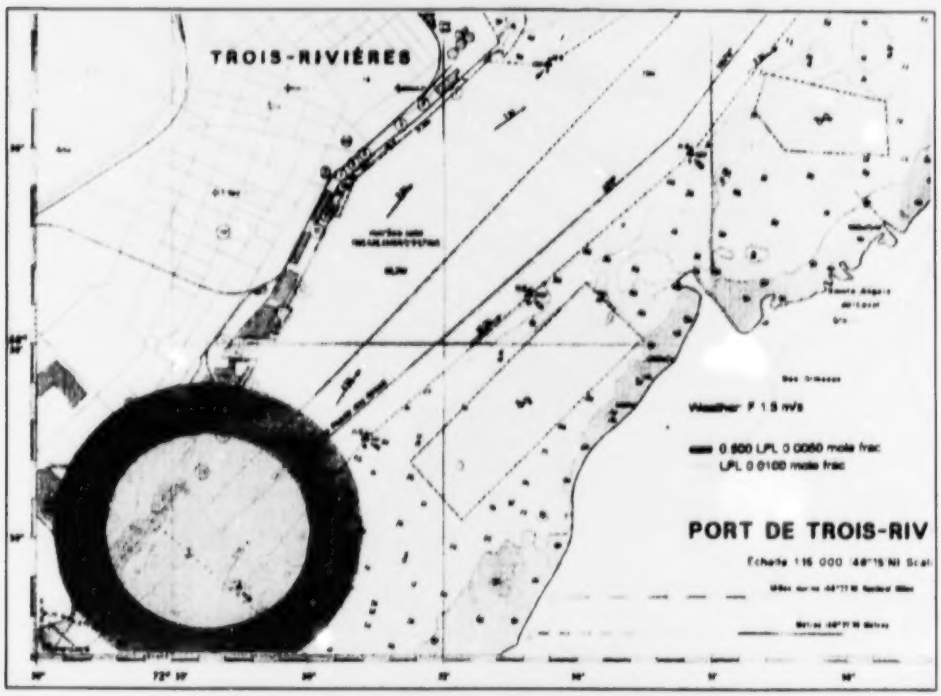



**Figure 16. Flash Fire Flame Envelope**

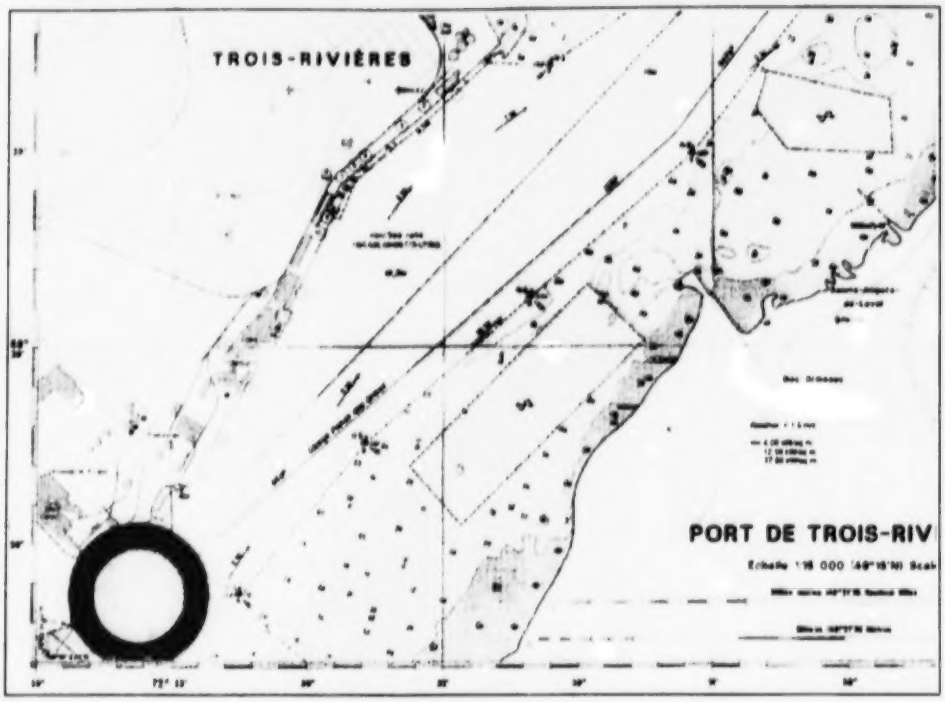



**Figure 17. Radiation Radii for Pool Fire**

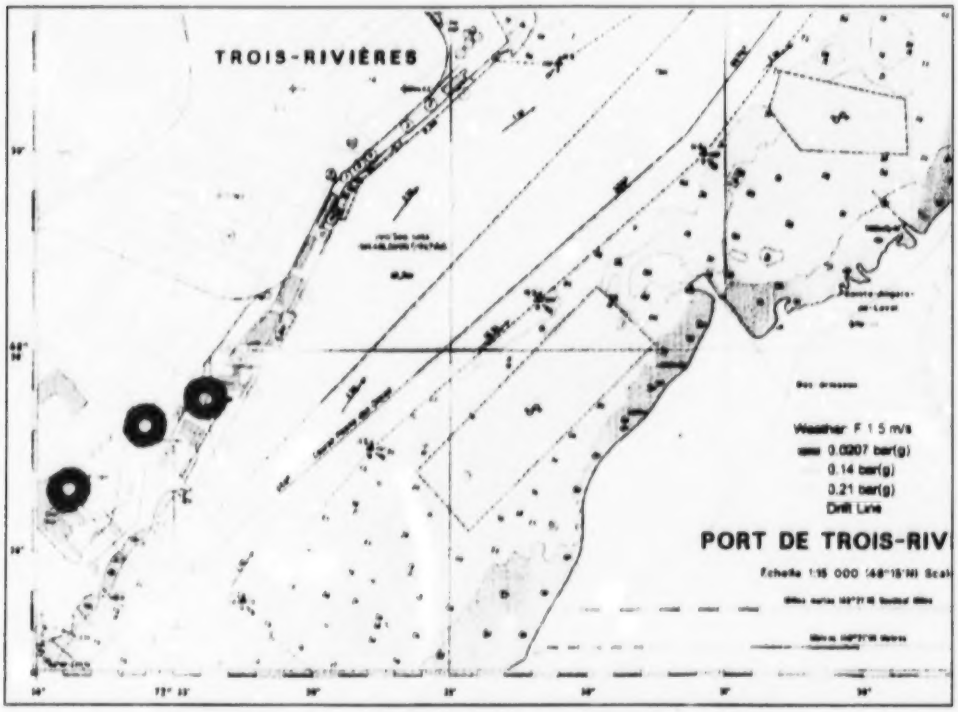



**Figure 18. Late Ignition Explosion Overpressure**

# 9 Conclusions and Recommendations

## *9.1 MSD Tool*

Comparisons of the MSD and CW data to accident data indicated the expected relationship between CW/MSD and accident rates for the areas studied. Validation of the MSD method using accident data was limited by the available data. As it is unlikely that sufficient accident data will ever be available, it will be necessary to continue to incorporate expert opinion into the MSD method. Improvements are possible through the use of MSD and assessment of results.

The MSD method and results reflect existing practice. This, along with the positive reception from stakeholders (including government and industry), suggests that the MSD method provides a systematic and logical method for assessing safety requirements and the level of risk on the river.

Future inclusion of other accident causes in the MSD tool is possible if supported by evidence. As well, the design enables consideration of other navigation safety measures such as differential global positioning system (DGPS), electronic chart display and information system (ECDIS) and MCTS.

## *9.2 Risk Analysis*

The risk analysis draws together the accident, traffic and consequence analysis work of sections 7 and 8. The accident analysis covered a wide area of the St. Lawrence River and provided a broader range of vessel and accident details than originally anticipated in the scope. The consequence analysis focused on two collision scenarios in the Trois Rivières area: one involving a gasoline tanker and the other a fuel oil tanker.

The frequency of a collision involving through traffic in the Pointe-des-Ormes area was indicated to be 8 in 22.5 years or 0.36 per year (see Appendix A, Table 10). There is a 15 percent chance that the vessel is an oil or oil product tanker (40/259, see Table 4).

The consequence magnitude for the oil spill scenario in Lac St. Pierre was measured as a probability of a spill of 1 350 $m^3$ given a collision. This probability is 0.013 (see Table 8). Therefore, the annual probability of a spill was measured as the annual probability of a collision involving a tanker (.054) times the conditional probability of the spill (0.013). Given these estimates, one would expect a medium-sized oil spill once every 1 428 years or 0.0007 per year (note: this estimate is just for the area of Pointe-des-Ormes).

**Table 8. Oil Spill Probability**

| Consequence Magnitude | Grounding | Collision | Striking |
|---|---|---|---|
| p(spill > 10 K t given a casualty) | 0.0006 | 0.0003 | 0.0001 |
| Average spill size | 10000 | 10000 | 10000 |
| p(spill > 136 & <10K t given a casualty) | 0.029 | 0.013 | 0.007 |
| Average spill size | 900 | 900 | 900 |
| p(spill < 136 t given a casualty) | 0.065 | 0.019 | 0.040 |
| Average spill size | 15 | 15 | 15 |

Source: Marine Navigation Safety System (10)

There are many ways of bringing the spill costs into perspective. A cost-benefit analysis was not required, but a valuation of the tanker collision risk was provided to indicate the costs of one of many possible risk scenarios. If the oil spill cost is $22.2 million, the annual cost in Pointe-des-Ormes is $15 580, however, vessel damages due to a collisions would be incurred once every three years and these could reach as high as $5.6 million per incident or $2 million per year.

The MSD tool was used to make numerous comparisons between the affect of vessel type, navigation conditions and aids to navigation configurations on safety in the St. Lawrence River in the Laurentian Region. A change in the level of service of aids to navigation proposed by AASL will have an effect on the safety in the river and the potential consequence costs. These changes in safety are documented in Appendix B. For example, a summer, low visibility scenario involving two container vessels in Course Pointe du Lac showed an increased risk of 28 percent. In this section, the channel width required for safe navigation (MSD) was less than the actual channel width (see Table 3).

### *9.3 Recommendations*

- The MSD tool will be released to workshop members for further review. A log should be kept of any changes so that the positioning relationships can be modified to reflect expert opinion.

- In light of the MSD analysis results for the three study areas, which showed a change in risk depending on the LOS of aids to navigation, any changes to current provision of aids to navigation or pilotage services should consider an MSD analysis for the waterway in question.

- The development team should work with CCG to investigate the effect of electronic aids to navigation, such as DGPS with ECDIS, on the positioning quality component in the MSD tool.

- The MSD tool and MNSS should be used to estimate potential consequence costs for a section of river and these estimates should be compared to various level of service provision costs.

- CCG should continue to develop and incorporate additional expert judgment into the model by applying the MSD method to additional segments of the river. Validation of the MSD method using accident data was limited by the available data. It is unlikely that sufficient accident data will ever be available and it will be necessary to continue to incorporate expert opinion into the MSD method to refine the precision of MSD estimates and broaden its applicability to different waterways.

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# Appendix A: Accident Analysis

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**Note: All 13 tables referenced in the body text of Appendix A are located at the end of this Appendix.**

## A1 Accident Analysis

The accident analysis in the main design document and this appendix was edited from an original analysis completed in June 1999, by John Shortreed, Diana Del Bel Belluz and Geoff Knapp of the Institute for Risk Research, University of Waterloo.

The objective of the accident analysis is to validate and confirm the approach used in the Minimum Safe Design (MSD) method for channel design. While there are over 20 years of data, the validation of the MSD method requires much more data to examine the details of the model, so the validation must be at some intermediate level which considers aggregated sections of the river and aggregated time periods. As indicated by the results, the accident analysis is sufficient to broadly confirm the method but the validity of the model details still depends on the careful elicitation of expert opinion. In addition, it will be seen that the data limitations preclude more extensive analysis of existing data.

An analysis of the Maritime Safety Information System (MARSIS) accident data for the St. Lawrence River was performed. The objectives of the analysis were: (a) to develop the risk profile of the river, especially with respect to groundings, collisions, and strikings involving tankers, merchant and passenger vessels; (b) to obtain accident rates for specific sections of the river for comparison to the MSD results and validation of the MSD methodology; and (c) to focus on accidents related specifically to shiphandling and positioning in the river, related to the provision of aids to navigation.

### *Overview of Approach*

The MARSIS database, for all of Canada for the period 1975-1997 was used as the base data. This data was reduced to reflect accidents in the St. Lawrence River, to focus on positioning and shiphandling related accidents, to eliminate accidents in ports, and so forth. Figure 1 documents the analysis steps taken to modify the accident data to obtain accident records relevant for the MSD study. A detailed explanation of each step in the analysis follows. In addition to the accident data, complementary exposure data was developed for the year 1995-96.

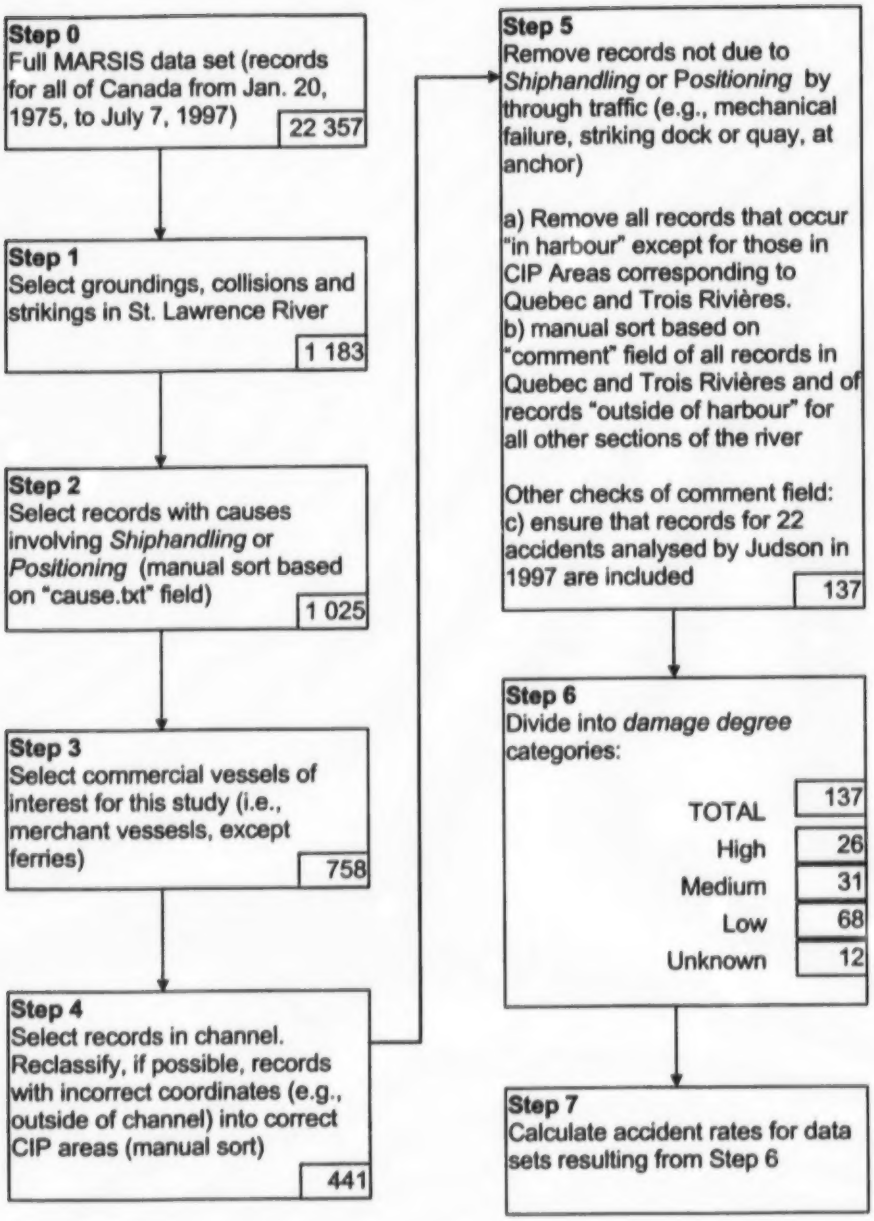
Step 0
Full MARSIS data set (records for all of Canada from Jan. 20, 1975, to July 7, 1997)
22 357
Step 1
Select groundings, collisions and strikings in St. Lawrence River
1 183
Step 2
Select records with causes involving *Shiphandling* or *Positioning* (manual sort based on "cause.txt" field)
1 025
Step 3
Select commercial vessels of interest for this study (i.e., merchant vessesls, except ferries)
758
Step 4
Select records in channel. Reclassify, if possible, records with incorrect coordinates (e.g., outside of channel) into correct CIP areas (manual sort)
441
Step 5
Remove records not due to *Shiphandling* or *Positioning* by through traffic (e.g., mechanical failure, striking dock or quay, at anchor)
a) Remove all records that occur "in harbour" except for those in CIP Areas corresponding to Quebec and Trois Rivières.
b) manual sort based on "comment" field of all records in Quebec and Trois Rivières and of records "outside of harbour" for all other sections of the river
Other checks of comment field:
c) ensure that records for 22 accidents analysed by Judson in 1997 are included
137
Step 6
Divide into *damage degree* categories:
TOTAL 137
High 26
Medium 31
Low 68
Unknown 12
Step 7
Calculate accident rates for data sets resulting from Step 6

**Figure 1. Overview of Data Selection Steps**

Step 0. MARSIS data

The MARSIS database contains data from reports filed on accidents occurring between January 20, 1975 and July 7, 1997. There were 22.5 years of data for all of Canada including records reported to SAR, CCG and TSB, which occurred outside the territorial waters of Canada. The records in the MARSIS database were received as a MapInfo table and the analysis was done using MapInfo GIS analysis tools and Excel database analysis tools.

Step 1. Select casualty types and accident location of interest

A MapInfo SQL query was used to strip away all accident records in MARSIS database except for the following types of accidents: groundings, collisions and strikings. Then, using the radius select tool in MapInfo, a series of circles were created to select those accident records for the St. Lawrence River from Montreal to Les Escoumins. A total of 1183 records were selected.

Step 1 produced data for the whole of the St. Lawrence River; however, in Step 4 the data was divided up into CIP (Call in Point) areas that divided the total study area into 19 geographical areas. Also in Step 4, accident records for vessels not using of the main navigation channel were deleted.

Step 2. Select accident causes that relate to shiphandling or positioning

Accidents caused by "human factors" or shiphandling or navigation errors, are of interest for this study because they might be reduced with improved aids to navigation. A breakdown of the "Set of 1183" records from Step 1 by the "cause1.txt" field of the MARSIS data base is shown in Table 1. Table 1 indicates which cause categories were selected as possibly relating to Shiphandling or Positioning; but in Step 5 these were examined in more detail and any accidents not due to Shiphandling or Positioning (e.g., mechanical failure, etc.) were removed. This step reduced the data to 1,025 records.

Step 3. Select vessel types of interest

A breakdown by vessel type of the "Set of 1,025" accidents possibly related to Shiphandling or Positioning are shown in Table 2. The following vessel types were removed because they were not deemed to be of interest for this study: Ferry; Government; Other_over_20m; Other_under_20m; Tug; Tug_with_oil_barge. This reduced the data set to 758 records. Table 2 gives a breakdown by vessel type and by casualty type for the 758 accident records.

Step 4. Select accidents for vessels in transit only

As indicated in step 1, the data was assigned to one of 19 CIP areas using MapInfo and the coordinate attached to the accident record. Some accidents fell outside the channel area (e.g., some were on land!) and these were removed from the data. Each accident removed for not being in a CIP area was examined by hand and, where possible (e.g. incorrect coordinates in record but able to locate correct CIP area), the accident records were assigned to the correct CIP area by B. Judson. This step resulted in a data set of 441 accidents.

Table 3 illustrates the distribution of the 441 accidents in terms of collisions, groundings and strikings. This is done both for those accidents that were retained in the 441 records (shown in bold type) and for those records that were removed (e.g., records for accidents upstream of Montreal).

Table 4 shows the 441 accidents in terms of the number of accident records in each of the 19 CIP areas that comprise the St. Lawrence study area and for the type of accident (collision, grounding and striking). Each CIP area is about 10 nmi long and the data is for 22.5 years. It can be seen that even at this level of aggregation there are many zero accident counts. Clearly, the data will not support any detailed examination of accident analysis, even though the waterway has the largest number of accident records in Canada.

Step 5. Elimination of non-related accidents

A number of manual sorts were done in this step to focus on accidents related to shiphandling and positioning errors in the channel that would be affected by aids to navigation. First, accidents listed in MARSIS as being "in harbours" were eliminated, except for Quebec City and Trois Rivières where the channel and the port are coincidental. Table 5 shows the result of this step, which reduced the number of accidents from 441 to 329.

Second, a manual sort was made of the remaining 329 accident records considering the following:

- removal of port accidents in Quebec City and Trois Rivières (e.g., records that contained the words "jetty", "quay", "port" and "dock"),
- removal of mechanical failure, etc., causes that were incorrectly coded in MARSIS,
- addition of accidents previously removed that on examination had been incorrectly coded in MARSIS, and
- addition of any accidents that have a TSB report for the accident but were not included.

This resulted in 137 accident records. Those records that involved touching the bank, a buoy or ice were retained.

Step 6. Divide into damage degrees

Table 6 gives the allocation of the MARSIS Damage Degree field to the three damage degrees defined for this study: Low, Medium and High. Twelve out of 137 records were not classified into damage degrees because their MARSIS Damage Degree was "unknown".

Step 7. Accident rates by CIP area by damage degrees

In order to calculate the accident rates by CIP area, an estimate of the annual traffic in each area was required. This was found from DADS Traffic for 1995-96, which provided data for every vessel by time and vessel type. Table 7 gives the results of the traffic count analysis for each CIP area and for each vessel type. Note that only traffic data for merchant vessels (with the exception of ferries) were used, and port movements are removed from the traffic counts shown in Table 7. Vessel types not included in the data (see Table 2) were excluded from the traffic counts. The traffic counts at the CIP were assumed to reflect traffic for the whole of the CIP area. The exposure (i.e., the number of vessels for the 22.5 years of accident data) was found by assuming that the 1995-96 data was representative of the 22.5 years.

Table 8 gives the accident rates for collisions, groundings and strikings, and for each CIP area for the overall accident rate and for the accident rate by Damage Degree. The accident rates were found from dividing the number of accidents by the exposure and expressing the rate in terms of "per nmi per 100,000 transits", i.e.:

$$\text{Accident rate for CIP Area}_x = \frac{(\text{Number of accidents in CIP area}_x \text{ from Step 6}) \times (100{,}000 \text{ transits})}{(\text{Annual traffic for CIP area}_x) \times (\text{track length in nmi through the CIP area}_x) \times (22.5 \text{ years})}$$

In Table 8, for example, consider CIP Area 5 "Escoumins" – the traffic estimate is 4,857 vessels per year, times 22.5 years, times the CIP area length of 16.7 nmi, resulting in an exposure of 1,825,017 vessel nmi. The total number of accidents is 3 and the rate, per 100,000 vessel nmi is 0.16, as shown in Table 8.

For each CIP Area, Table 8 indicates the average accident rate and standard deviation. Shown in bold typeface are any accident rates that are more than 1 standard deviation higher than the mean, a value which is expected in only about 15 percent of the observations. CIP areas that have high accident rates by this

criteria, include: "Quebec", "Grondines" and "Pointe-Des-Ormes" considering the "Total" accident rate. When only the "High" Damage Degree accidents are considered, the CIP areas with high accident rates by this criteria are: "Saint-Augustin", "Grondines", and "Pointe-Des-Ormes".

Table 8 indicates that there is a lower accident rate from Escoumins to Quebec City than from Quebec City to Montreal. However, examination of the accident counts shown in Table 8 indicate that the data is limited as there are many zero counts. For High Damage Degree accidents there are 26 accidents for the 22.5 years or about 1.2 accidents per year.

To give a more complete picture of the accident locations and accident types, further details of the 137 accidents are provided in Tables 9 and 10.

## A2 MSD Results and Accident Rates

The comparison of MSD results and accident rates was done as a form of validation of the MSD method to confirm that Channel Width / Minimum Safe Design (CW/MSD) is related to the accident rate. It is expected that a lower value of CW/MSD is associated with a higher accident rate. In addition, the accident rates for summer were compared to those for the winter.

The MSD method has been shown to accurately reflect the expert opinion used in the development of the existing channel widths since there is a consistent relationship between the MSD estimate and the channel width provided. For example, for the sections in CIP areas 10, 19 and 20 (areas with well defined two-way channels that are constrained), Figure 2 illustrates the relationship between MSD for summer low visibility and the channel width currently provided. The correlation between the MSD values and the channel width provided is indicative of how the channel width has been changed, over time, to reflect the minimum safe width required for navigation of the river. The linear relationship shown in Figure 2 indicates a ratio of CW/MSD of 1.16, or a "factor of safety" of only 16 percent.

Even with limitations of the accident data and the CW/MSD estimates it is possible to see if higher accident rates are associated with lower values of CW/MSD. Tables 11 and 12 provide data, for summer (May to September inclusive) and winter. The data in these tables is similar to Table 8 for the annual data. The summer and winter information was found by reanalyzing the DADS data base and recalculating the accident rates for both summer and winter. In each table the accident rates for each CIP area and also for the overall river are calculated. For the overall river the accident rate for summer is 0.35 navigational related accidents per 100,000 vessel-nmi. For winter the value is 0.65 and for the overall year the rate is 0.50 navigational accidents per 100.000 vessel-nmi.

The difference between summer and winter accident rates is just significant at the 5 percent level of significance.

The accident rate data and the CW/MSD ratio (channel width divided by the minimum safe channel width) for CIP areas 6-7, 10-11 and 19-20 are summarized in Table 13. The MSD values used to calculate CW/MSD are the median MSD value for all the sections in each CIP area. The data in Table 13 is plotted in Figure 3.

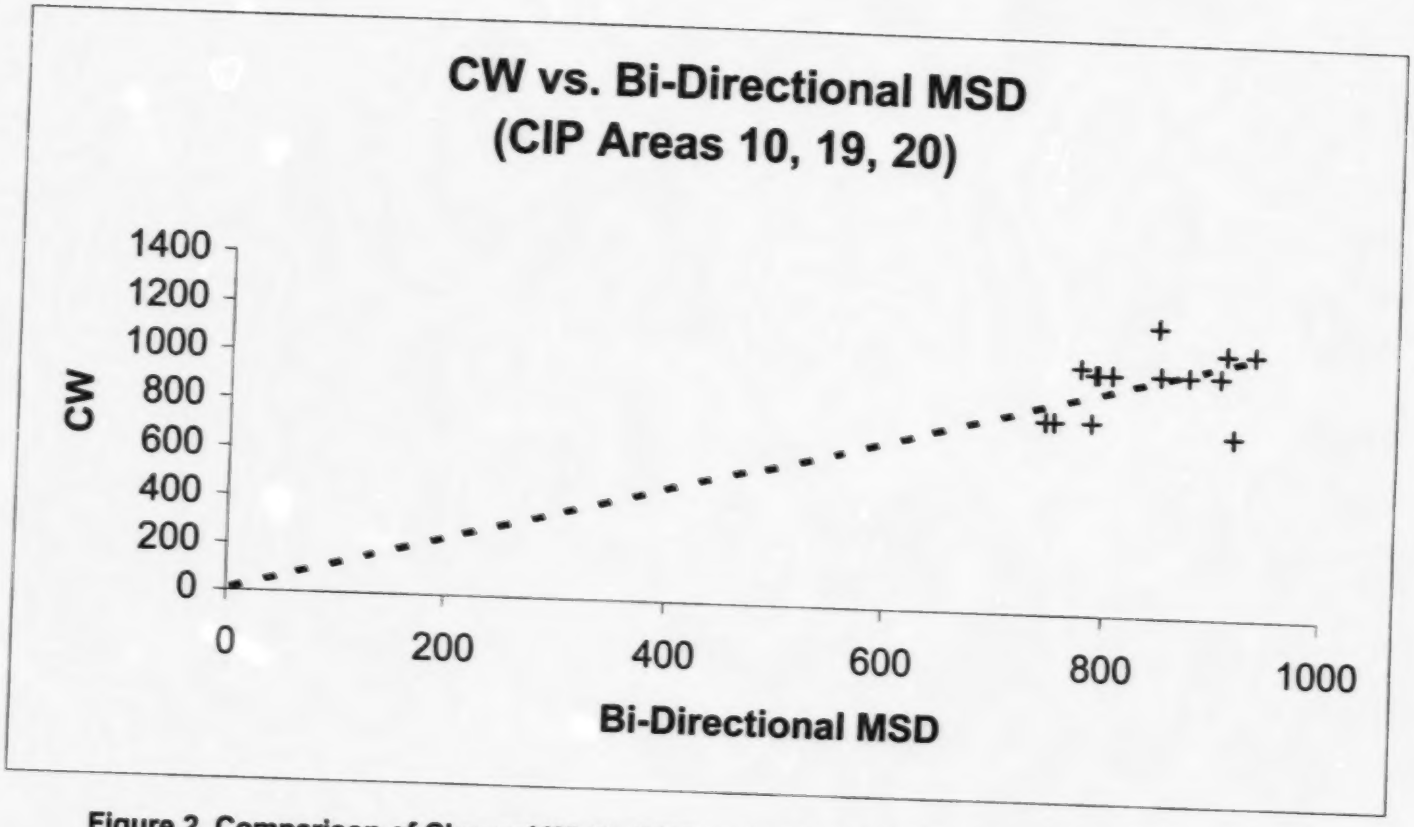


**Figure 2. Comparison of Channel Width (CW) and Estimated MSD (Summer Low Visibility)**

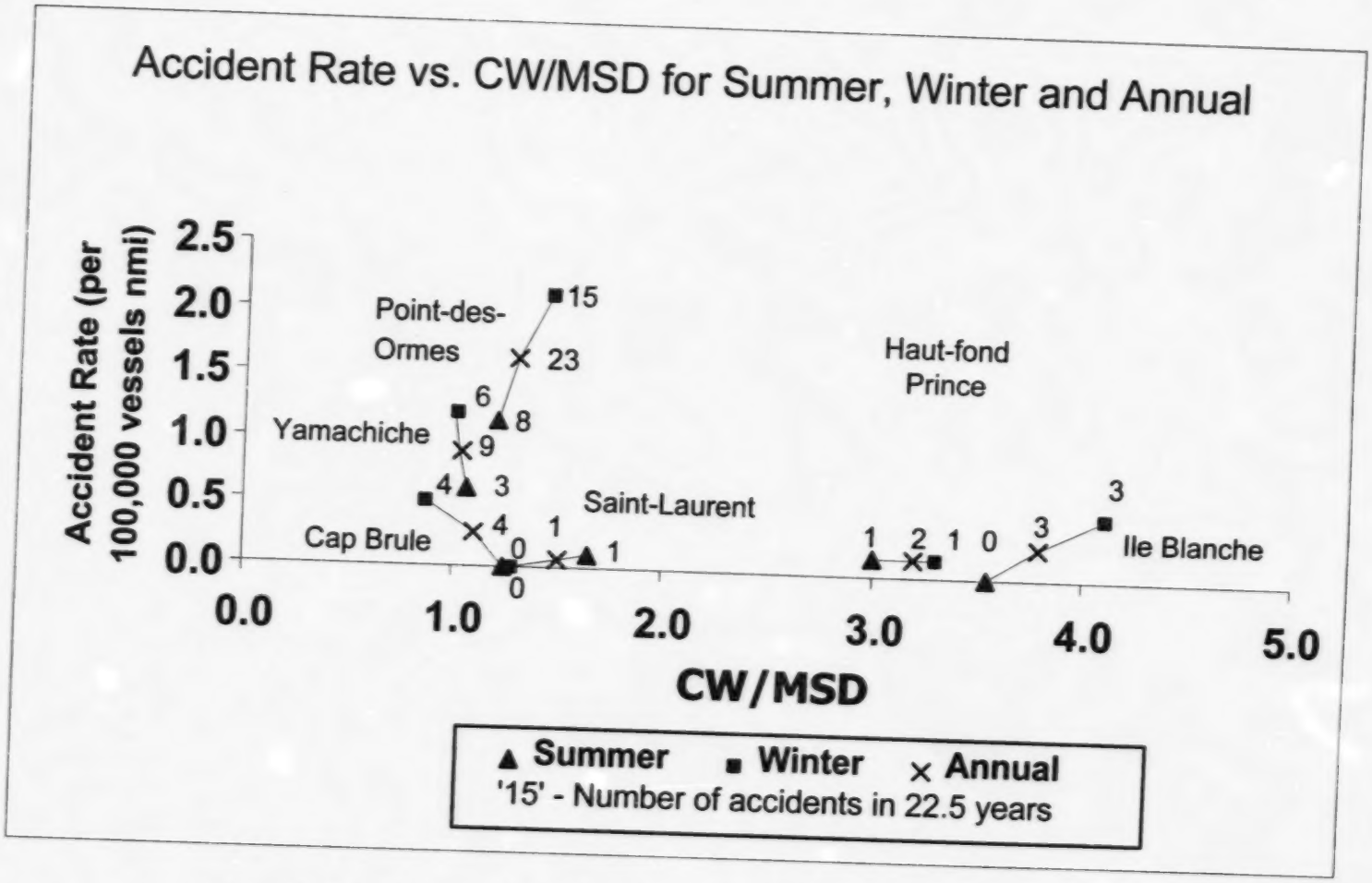


**Figure 3. Comparison of Accident Rates for Summer, Winter and Annual**

Figure 3 plots the median value for a CIP area of CW/MSD versus the accident rate for the data in Table 13. For each CIP area there are three points: one for summer conditions, one for winter conditions, and one for the full year or annual conditions. It is clear that the data is limited with most observations having less than 4 accidents in the 22.5 year period, which implies a 25 percent range of error for plus or minus one accident. However, the data does confirm the general expectation of increasing accident rates with lower values of CW/MSD. This relationship is consistent for both winter and summer conditions as well as for annual data – there is a relationship between low CW/MSD values (i.e. close to 1.0) and high accident rates.

Figure 3 indicates that the comparison between winter and summer shows a similar relationship between CW/MSD ratio and accidents but the winter accident rates are higher than the summer accident rates.

In Figure 3 and Table 13 the two points with the most data are CIP areas 19 and 20. While these areas have low values of CW/MSD and high accident rates relative to other CIP areas, it would be expected that area 20 would have a higher accident rate than area 19 when the reverse is the case. Section 19 has one section with a CW/MSD of 0.82, which might suggest that this section contributes to the higher accident rate. However, Figure 4, which plots the actual locations of accidents in CIP 19-20 and the section CW/MSD values, does not support this interpretation. In Figure 4 the density of accident data for specific locations is limited and it is difficult to draw any meaningful conclusions in terms of differences between sections. However, it should be noted that sections in these two CIP areas have accident rates that are considerably higher than most other areas in the river. Thus the general relationship in Figure 3 cannot be observed at a finer level of detail of Figure 4, due to limitations of data.

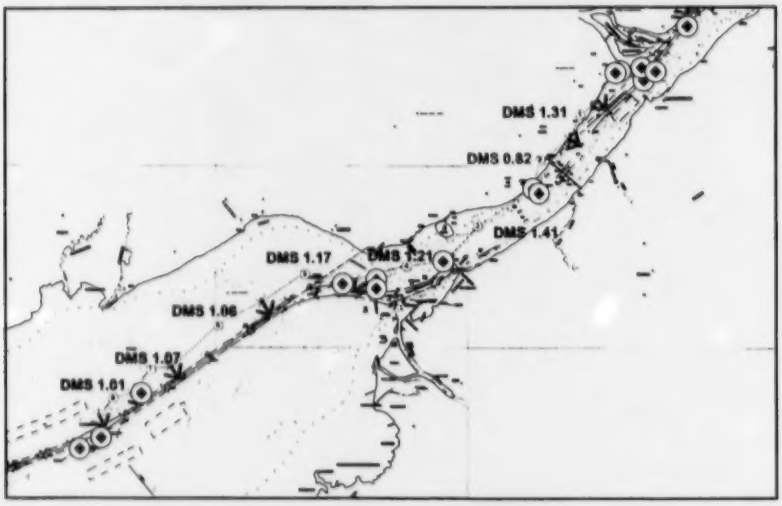


**Figure 4. Detailed Comparison of CW/MSD and Individual Accident Locations in CIP Areas 19-20**

## A3 Conclusions

Comparisons of the MSD and channel width (CW) data to accident data indicate the expected relationship between CW/MSD and accident rates for the six CIP areas studied.

Validation of the MSD method using accident data is limited by the available data. This is good for marine safety. It is unlikely that sufficient accident data will ever be available and it will be necessary to continue to incorporate expert opinion into the MSD method.

The MSD method results are correlated to existing practice and this, along with the positive reception from stakeholders, suggests that the MSD method provides a systematic and logical method for assessing safety requirements and the level of risk on the river.

Summer accident rates are significantly less than winter accident rates. The reasons for this difference are clearly related to the difficulties of winter operations, but the specific risk factors are not available from the accident analysis.

Through a process of using the MSD method and continuous improvement by review and assessment of results, it will be possible to add modifications to MSD which are supported by evidence.

## A4 Tables

Table 1. Selection of Potential Shiphandling and Positioning Accidents by MARSIS Cause Classification (Step 2)

| Cause1.txt value | Select* | Count | Cause1.txt value | Select* | Count |
|---|---|---|---|---|---|
| ANCHOR DRAGGED | | 3 | MECHANICAL GENERAL OTHER | | 11 |
| ATMOSPHERIC CONDITIONS (GENERAL) | | 6 | NO CAUSE | | 1 |
| AUTOMATED MACHINERY CONTROLS | | 3 | OBSTRUCTION | | 3 |
| BOULDER IN CHANNEL | | 1 | OBSTRUCTION IN CHANNEL | | 2 |
| BREAKER DROPPED OUT | | 2 | OIL LINE | | 2 |
| **BUOY NOT IN POSITION (GENERAL)** | X | 2 | OIL PRESSURE, LACK OF | | 3 |
| CARGO GEAR, POORLY RIGGED | | 1 | PIER WHARF, DESIGN POOR | | 1 |
| **CAUSE NOT KNOWN** | X | 45 | PIPE, WATER CIRCULATION | | 1 |
| CHANNEL, SHALLOW | | 1 | PROPELLER, CONTROLLABLE PITCH | | 7 |
| **CHARTWORK & NAVIGATION EQUIP. USE OTHER** | X | 1 | RUDDER – GENERAL | | 1 |
| **CONTROL, ENGINE BRIDGE UNIT** | X | 5 | **SEAS GENERAL** | X | 3 |
| **CURRENT (GENERAL)** | X | 14 | **SHIPHANDLING GENERAL** | X | 5 |
| DEEP DRAFT | | 1 | STEERING CONTROL, ELECTRICAL | | 7 |
| DESIGN OF SHIP SHORTCOMINGS | | 1 | STEERING CONTROL, HYDRAULIC | | 4 |
| **DIFFICULT HANDLING SHIP** | X | 1 | STEERING CONTROL, MECHANICAL | | 5 |
| ELECTRICAL FAILURE CONDITION, OTHER | | 6 | STEERING GEAR | | 17 |
| ENGINE, MAIN | | 14 | STRESS FRACTURE | | 1 |
| ENGINE, MAIN STALLED | | 14 | STRUCTURAL CONDITION, OTHER | | 2 |
| EQUIPMENT, IMPROPERLY MAINTAINED | | 1 | **SUCTION BANK** | X | 8 |
| EQUIPMENT, OTHER | | 4 | **SUCTION INTERSHIP** | X | 1 |
| **ERROR IN JUDGEMENT (GENERAL)** | X | 19 | **SURGE FROM OTHER SHIP** | X | 1 |
| FENDERS FAILURE | | 2 | THRUSTER, BOW | | 1 |
| FENDERS MISSING | | 3 | TOW LINE – PARTED | | 5 |
| FUEL CONTAMINATED | | 4 | VESSEL GENERAL CONDITION, OTHER | | 2 |
| FUSE FAILED | | 1 | **VISIBILITY** | X | 11 |
| GENERATOR, ELECTRICAL SIDE | | 8 | WASH FROM OTHER SHIP | | 1 |
| GENERATOR, MECHANICAL SIDE | | 3 | **WIND** | X | 20 |
| **HUMAN FACTOR (GENERAL)** | XXX | 364 | **WIND GUSTY** | X | 6 |
| HYDRAULIC LINE | | 1 | **WIND SQUALL** | X | 1 |
| **ICE** | X | 31 | **(blank)** | XX | 487 |
| LIGHTSHIP | | 1 | | | |
| | | | **Grand Total** | | 1,183 |
| | | | **Subtotal "Selected"** | | 1,025 |

* Legend of records analyzed is as follows (Note: all data is pooled for analysis results in this report):

XXX Initially, only the 364 records due to "HUMAN FACTOR (GENERAL)" were included in the analysis shown Appendix B of the report *Risk Based Design Method for the Channel in the St. Lawrence River* issued on September 1, 1998.

XX The analyses of the 487 records with "blank" in the Cause.txt field were provided in *the Additional Accident Analysis Addendum* issued on September 29, 1998.

X All other selected "Cause.txt" categories added 173 records for analysis in October 1998. All results given in this report are for the full data set, i.e., 1,025 records.

Table 2. "Select Commercial Vessels of Interest" by Accident Type (Step 3)

| VESSEL_TYPE | Select | COLLISION | GROUNDING | STRIKING | Grand Total |
|---|---|---|---|---|---|
| **Bulk** | **X** | **128** | **110** | **136** | **374** |
| **Cargo** | **X** | **63** | **43** | **79** | **185** |
| **Chemical_Tanker** | **X** | **6** | **5** | **7** | **18** |
| **Container** | **X** | **7** | **6** | **11** | **24** |
| Ferry | | 13 | 6 | 11 | 30 |
| **Fishing** | **X** | **3** | **3** | **1** | **7** |
| Government | | 23 | 18 | 26 | 67 |
| **LPG_LNG_Carrier** | **X** | **0** | **1** | **0** | **1** |
| Other_over_20m | | 9 | 12 | 7 | 28 |
| Other_under_20m | | 24 | 2 | 7 | 33 |
| **Passenger** | **X** | **12** | **11** | **21** | **44** |
| **Tanker_over_50000DWT** | **X** | **0** | **0** | **2** | **2** |
| **Tanker_under_50000DWT** | **X** | **40** | **28** | **35** | **103** |
| Tug | | 46 | 32 | 27 | 105 |
| Tug with oil barge | | 2 | 2 | 0 | 4 |
| Grand Total | | 376 | 279 | 370 | 1025 |
| **Subtotal selected for Step 4** | | **259** | **207** | **292** | **758** |

Table 3. Selected Records in Channel by Accident Type (Step 4)

| | CASUALTY_TYPE | | | |
|---|---|---|---|---|
| Classification Category* | COLLISION | GROUNDING | STRIKING | Grand Total |
| **INSIDE** | **137** | **153** | **148** | **438** |
| MONTREAL | 110 | 41 | 130 | 281 |
| **MOVED IN** | **0** | **3** | **0** | **3** |
| N/A | 1 | 3 | 4 | 8 |
| NO | 0 | 2 | 0 | 2 |
| OUTSIDE | 11 | 5 | 10 | 26 |
| Grand Total | 259 | 207 | 292 | 758 |
| **Subtotal selected** | **137** | **156** | **148** | **441** |

* Legend of Classification Categories:

| | |
|---|---|
| INSIDE: | within CIP Areas |
| OUTSIDE: | outside CIP Areas |
| N/A: | outside and reclassified as not applicable casualty or cause |
| MOVED IN: | outside and moved into CIP area because of proximity and relevance |
| MONTREAL: | outside CIP Area 25 (Montreal East) |

Table 4. Accidents by CIP Area and Type of Casualty (Step 4).

| CIP_AREA | | CASUALTY_TYPE | | | |
|---|---|---|---|---|---|
| # | Name | COLLISION | GROUNDING | STRIKING | Grand Total |
| 5 | ESCOUMINS | 4 | 1 | 2 | 7 |
| 6 | HAUT-FOND PRINCE | 0 | 2 | 0 | 2 |
| 7 | ILE BLANCHE | 1 | 2 | 0 | 3 |
| 0 | CAP AU SAUMON | 0 | 1 | 0 | 1 |
| 8 | CAP-AUX-OIES | 6 | 3 | 4 | 13 |
| 9 | GRAND-POINT | 0 | 0 | 0 | 0 |
| 10 | CAP BRULE | 0 | 8 | 0 | 8 |
| 11 | ST. LAURENT | 2 | 2 | 0 | 4 |
| 13 | QUEBEC | 43 | 12 | 89 | 144 |
| 14 | ST. AUGUSTIN | 3 | 8 | 2 | 13 |
| 15 | DONNACONA | 3 | 12 | 0 | 15 |
| 16 | GRONDINES | 4 | 17 | 2 | 23 |
| 17 | BATISCAN | 3 | 16 | 5 | 24 |
| 19 | POINTE-DES-ORMES (Trois Rivières) | 20 | 15 | 19 | 54 |
| 20 | YAMACHICHE | 4 | 6 | 0 | 10 |
| 21 | ILE DES BARQUES | 18 | 26 | 9 | 53 |
| 22 | TRACY | 2 | 9 | 3 | 14 |
| 24 | CAP ST. MICHEL | 0 | 0 | 0 | 0 |
| 25 | MONTREAL EST | 24 | 16 | 13 | 53 |
| | Grand Total | 137 | 156 | 148 | 441 |

Table 5. Elimination of Non-related Port Accidents (Step 5a)

| | In Harbour | Outside of Harbour | Total |
|---|---|---|---|
| Trois Rivières & Quebec City | **169** | **29** | 198 |
| All Other CIP Areas | 112 | **131** | 243 |
| Grand Total | 281 | 160 | 441 |
| Subtotal Selected for Manual Sort in Step 5 | **169** | **160** | **329** |

Table 6. Breakdown of Accidents by Damage Degree

| DAMAGE_DEG | | Consequence | COLLISION | GROUNDING | STRIKING | Grand |
|---|---|---|---|---|---|---|
| # | Description | Level | | | | Total |
| 0 | | Low | 0 | 0 | 1 | 1 |
| 1 | NONE | Low | 2 | 11 | 0 | 13 |
| 11 | DAMAGED | Low | 3 | 1 | 1 | 5 |
| 12 | NONE APPARENT | Low | 4 | 30 | 1 | 35 |
| 14 | SCRATCH-SCUFF | Low | 2 | 3 | 0 | 5 |
| 15 | DENT | Low | 1 | 2 | 2 | 5 |
| 16 | VERY MINOR | Low | 0 | 2 | 2 | 4 |
| 17 | MINOR | Medium | 8 | 1 | 6 | 15 |
| 21 | HOLED | High | 0 | 11 | 1 | 12 |
| 22 | SOME | Medium | 9 | 4 | 0 | 13 |
| 24 | CONSIDERABLE | Medium | 1 | 1 | 1 | 3 |
| 31 | EXTENSIVE | High | 2 | 9 | 0 | 11 |
| 32 | VERY EXTENSIVE | High | 2 | 1 | 0 | 3 |
| 99 | NOT KNOWN | Unknown | 7 | 4 | 1 | 12 |
| | Grand Total | | 41 | 80 | 16 | 137 |
| SUMMARY By Consequence Class | | | | | | |
| | Subtotal (Low) | | 12 | 49 | 7 | 68 |
| | Subtotal (Medium) | | 18 | 6 | 7 | 31 |
| | Subtotal (High) | | 4 | 21 | 1 | 26 |
| | Subtotal (Unknown) | | 7 | 4 | 1 | 12 |
| | Grand Total | | 41 | 80 | 16 | 137 |

Table 7. Annual Traffic Counts from DADS (12 months—1995-1996)

| VESSEL TYPE | CIP AREA NUMBER | | | | | | | | | | | | | | | | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 25 | |
| BARGES | 6 | 2 | 4 | 5 | 5 | 5 | 5 | 5 | 7 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 64 |
| BARGES SELF-PROPELLED | 2 | 2 | 0 | 2 | 2 | 1 | 20 | 17 | 3 | 6 | 6 | 6 | 7 | 3 | 6 | 6 | 0 | 0 | 0 | 89 |
| COAST GUARD ICEBREAKER | 83 | 74 | 94 | 83 | 76 | 87 | 91 | 98 | 47 | 46 | 41 | 26 | 24 | 58 | 39 | 26 | 14 | 12 | 12 | 1031 |
| COAST GUARD PATROL | 5 | 8 | 21 | 10 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 52 |
| COAST GUARD RESCUE | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 56 |
| COAST GUARD SCIENTIFIC | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 21 | 16 | 18 | 20 | 14 | 8 | 25 | 12 | 15 | 5 | 6 | 4 | 173 |
| COAST GUARD SUPPLY | 24 | 11 | 18 | 25 | 24 | 25 | 38 | 47 | 26 | 39 | 37 | 44 | 60 | 115 | 124 | 173 | 60 | 50 | 44 | 984 |
| COAST GUARD TENDER | 1 | 1 | 0 | 1 | 1 | 1 | 2 | 21 | 3 | 6 | 5 | 1 | 1 | 1 | 1 | 7 | 9 | 9 | 8 | 79 |
| DREDGE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 10 |
| HOVERCRAFT | 2 | 2 | 1 | 4 | 1 | 2 | 2 | 4 | 5 | 10 | 10 | 12 | 11 | 68 | 64 | 48 | 30 | 33 | 44 | 353 |
| MERCHANT (TANKER) | 566 | 558 | 549 | 561 | 564 | 563 | 561 | 563 | 550 | 637 | 639 | 640 | 638 | 615 | 619 | 621 | 695 | 733 | 961 | 11833 |
| MERCHANT BULK | 2339 | 2528 | 2424 | 2337 | 2335 | 2325 | 2323 | 2324 | 2268 | 2305 | 2305 | 2302 | 2311 | 2156 | 2179 | 2178 | 1940 | 1992 | 2002 | 42873 |
| MERCHANT CHEMICAL | 316 | 325 | 319 | 318 | 319 | 317 | 318 | 315 | 293 | 244 | 243 | 244 | 246 | 237 | 236 | 234 | 231 | 231 | 228 | 5214 |
| MERCHANT CONTAINER | 670 | 671 | 665 | 668 | 673 | 677 | 672 | 673 | 673 | 676 | 675 | 669 | 673 | 669 | 670 | 669 | 669 | 669 | 671 | 12752 |
| MERCHANT FERRY | 13 | 9 | 14 | 20 | 12 | 17 | 19 | 20 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 147 |
| MERCHANT GASOLINE | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 38 |
| MERCHANT GENERAL/BULK | 494 | 559 | 522 | 504 | 500 | 493 | 487 | 490 | 462 | 424 | 423 | 419 | 420 | 380 | 383 | 383 | 363 | 367 | 371 | 8444 |
| MERCHANT LIQUEFIED GAS | 8 | 8 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 151 |
| MERCHANT ORE | 93 | 92 | 92 | 92 | 94 | 93 | 92 | 93 | 94 | 94 | 94 | 94 | 94 | 91 | 94 | 96 | 3 | 4 | 4 | 1503 |
| MERCHANT ORE/BULK/OIL | 42 | 42 | 41 | 42 | 42 | 42 | 42 | 41 | 33 | 20 | 20 | 20 | 20 | 18 | 18 | 18 | 18 | 18 | 19 | 556 |
| MERCHANT PASSENGER | 301 | 52 | 290 | 321 | 321 | 329 | 347 | 396 | 88 | 111 | 112 | 126 | 131 | 131 | 131 | 134 | 137 | 141 | 144 | 3743 |
| MERCHANT REEFER | 18 | 20 | 17 | 18 | 18 | 17 | 17 | 18 | 17 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 300 |
| MERCHANT RO/RO | 260 | 266 | 235 | 263 | 244 | 245 | 246 | 245 | 249 | 248 | 249 | 250 | 250 | 247 | 247 | 247 | 246 | 246 | 246 | 4729 |
| OTHERS | 24 | 22 | 25 | 29 | 25 | 26 | 26 | 26 | 20 | 23 | 23 | 23 | 23 | 26 | 27 | 28 | 23 | 22 | 19 | 460 |
| SPECIAL PURPOSE | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 9 | 43 | 36 | 110 |
| SPECIAL RESEARCH VESSEL | 3 | 23 | 10 | 3 | 3 | 3 | 4 | 7 | 8 | 13 | 13 | 13 | 16 | 43 | 24 | 35 | 11 | 11 | 17 | 260 |
| SPECIAL PURPOSE SUPPLY VSL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| SPECIAL PURPOSE TOUR | 46 | 0 | 45 | 60 | 38 | 33 | 33 | 35 | 22 | 46 | 46 | 46 | 46 | 45 | 44 | 44 | 44 | 46 | 46 | 765 |
| SPECIAL PURPOSE TRAINING VSL | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 5 | 6 | 11 | 11 | 11 | 10 | 18 | 6 | 4 | 4 | 4 | 4 | 100 |
| TUGS | 96 | 109 | 78 | 117 | 111 | 128 | 132 | 149 | 118 | 119 | 119 | 117 | 115 | 113 | 147 | 144 | 121 | 234 | 163 | 2430 |
| TUGS OCEAN | 17 | 26 | 16 | 17 | 17 | 16 | 16 | 16 | 18 | 18 | 18 | 18 | 18 | 16 | 16 | 16 | 21 | 22 | 25 | 347 |
| TUGS SUPPLY | 7 | 7 | 4 | 8 | 12 | 14 | 14 | 14 | 10 | 11 | 11 | 12 | 12 | 14 | 14 | 14 | 8 | 8 | 9 | 203 |
| WARSHIP SURFACE | 22 | 23 | 20 | 23 | 23 | 22 | 22 | 23 | 17 | 20 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 386 |
| WARSHIP-GENERAL | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 91 |
| YACHT POWER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| (blank) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Grand Total | 5471 | 5453 | 5523 | 5552 | 5483 | 5507 | 5557 | 5689 | 5075 | 5185 | 5179 | 5166 | 5190 | 5145 | 5158 | 5203 | 4713 | 4953 | 5129 | 100331 |
| Subtotal MERCHANT (except ferries) | 4849 | 4857 | 4928 | 4871 | 4876 | 4866 | 4869 | 4923 | 4488 | 4535 | 4535 | 4538 | 4557 | 4321 | 4354 | 4357 | 4080 | 4179 | 4424 | 87407 |

## Table 8. Annual Accident Rates by CIP Area and Damage Degree

| CIP Area | | | | | Total | | Breakdown by Damage Degree *** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual Traffic** | Length | Traffic nmi | Accident | Annual | High | | Medium | | Low | |
| # | Name | Count (95/96) | (nmi, rounded) | (Count x nmi actual) | (Count per 22.5 years) | Accident RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* | Count per 22.5 years | Annual RATE* |
| 5 | ESCOUMINS | 4,857 | 17 | 81112 | 3 | 0.16 | 0 | 0.00 | 0 | 0.00 | 3 | 0.16 |
| 6 | HAUT-FOND PRINCE | 4,928 | 13 | 65542 | 2 | 0.14 | 2 | 0.14 | 0 | 0.00 | 0 | 0.00 |
| 7 | ILE BLANCHE | 4,871 | 11 | 55042 | 3 | 0.24 | 0 | 0.00 | 2 | 0.16 | 1 | 0.08 |
| 0 | CAP AU SAUMON | 4,849 | 19 | 90676 | 1 | 0.05 | 1 | 0.05 | 0 | 0.00 | 0 | 0.00 |
| 8 | CAP-AUX-OIES | 4,876 | 21 | 102396 | 1 | 0.04 | 0 | 0.00 | 0 | 0.00 | 1 | 0.04 |
| 9 | GRAND-POINT | 4,866 | 16 | 77856 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 10 | CAP BRULE | 4,869 | 14 | 69627 | 4 | 0.26 | 2 | 0.13 | 0 | 0.00 | 2 | 0.13 |
| 11 | ST. LAURENT | 4,923 | 16 | 78768 | 1 | 0.06 | 0 | 0.00 | 0 | 0.00 | 1 | 0.06 |
| 13 | QUEBEC | 4,488 | 10 | 44431 | 23 | **2.30** | 1 | 0.10 | 7 | **0.70** | 10 | **1.00** |
| 14 | ST. AUGUSTIN | 4,535 | 12 | 53967 | 8 | 0.66 | 4 | **0.33** | 3 | 0.25 | 1 | 0.08 |
| 15 | DONNACONA | 4,535 | 14 | 62130 | 6 | 0.43 | 0 | 0.00 | 2 | 0.14 | 3 | 0.21 |
| 16 | GRONDINES | 4,538 | 14 | 61263 | 17 | **1.23** | 5 | **0.36** | 3 | 0.22 | 8 | **0.58** |
| 17 | BATISCAN | 4,557 | 16 | 72912 | 13 | 0.79 | 2 | 0.12 | 1 | 0.06 | 10 | **0.61** |
| 19 | POINTE-DES-ORMES | 4,321 | 15 | 63087 | 23 | **1.62** | 5 | **0.35** | 7 | **0.49** | 9 | **0.63** |
| 20 | YAMACHICHE | 4,354 | 10 | 44411 | 9 | 0.90 | 2 | 0.20 | 4 | **0.40** | 3 | 0.30 |
| 21 | ILE DES BARQUES | 4,357 | 14 | 62305 | 11 | 0.78 | 0 | 0.00 | 2 | 0.14 | 7 | 0.50 |
| 22 | TRACY | 4,080 | 12 | 50592 | 4 | 0.35 | 0 | 0.00 | 0 | 0.00 | 4 | 0.35 |
| 24 | CAP ST. MICHEL | 4,179 | 11 | 45969 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 25 | MONTREAL EST | 4,424 | 9 | 38046 | 8 | 0.93 | 2 | 0.23 | 0 | 0.00 | 5 | **0.58** |
| Grand Total | | | | 1220132 | 137 | 0.50 | 26 | | 31 | | 68 | |
| CASUALTY TYPE | | | | | | | | | | | | |
| Collisions | | | | | 41 | | 4 | | 18 | | 12 | |
| Groundings | | | | | 80 | | 21 | | 6 | | 49 | |
| Strikings | | | | | 16 | | 1 | | 7 | | 7 | |
| Mean | | | | | | 0.58 | | 0.11 | | 0.14 | | 0.28 |
| Standard Deviation | | | | | | 0.62 | | 0.13 | | 0.20 | | 0.29 |
| Mean + 1 SD | | | | | | 1.20 | | 0.24 | | 0.34 | | 0.57 |

*e.g., for Escoumins: 4857 x 16.7 = 81112 vessel miles per year. 3/22.5 = .13 accidents per year or per 81112 nmi, or .16 accidents per 100000 nmi travelled. Accident data from 1/20/75 to 7/7/97.

** Includes all merchant vessels except for ferries for one year (95-96).

*** For 9 percent of the Set of 137 records, Damage Degree is "unknown". These records are included in the Grand Total only.

The CIP areas with rates more than 1 SD above the mean are shown in bold typeface.

Table 9. Classification of 137 Accidents by MARSIS Area and Accident Type (Step 5b)

| MARISIS_AREA | CASUALTY TYPE | | | |
|---|---|---|---|---|
| | COLLISION | GROUNDING | STRIKING | Grand Total |
| BAY | 0 | 1 | 0 | 1 |
| CANAL – INCLUDING SEAWAY | 2 | 5 | 2 | 9 |
| CHANNEL – APPROACH (GENERAL) | 2 | 4 | 0 | 6 |
| CHANNEL – STRAIT | 8 | 7 | 0 | 15 |
| HARBOUR – WITHIN I.E. IMMEDIATE AREA | 11 | 5 | 5 | 21 |
| HARBOUR AREA – GENERAL | 2 | 4 | 2 | 8 |
| LAKE | 0 | 3 | 1 | 4 |
| LOCK | 0 | 0 | 1 | 1 |
| PILOT BOARDING/DISEMBARKING AREA – APPROACHING | 1 | 0 | 0 | 1 |
| PILOT BOARDING/DISEMBARKING AREA – LEAVING | 1 | 0 | 0 | 1 |
| RIVER | 14 | 51 | 5 | 70 |
| Grand Total | 41 | 80 | 16 | 137 |

Table 10. Classification of 137 Accidents in Table 9 by CIP Area and Accident Type (Step 5b)

| CIP Area | | Casualty Type | | | |
|---|---|---|---|---|---|
| # | Name | COLLISION | GROUNDING | STRIKING | Grand Total |
| 5 | ESCOUMINS | 2 | 1 | 0 | 3 |
| 6 | HAUT-FOND PRINCE | 0 | 2 | 0 | 2 |
| 7 | ILE BLANCHE | 1 | 2 | 0 | 3 |
| 0 | CAP AU SAUMON | 0 | 1 | 0 | 1 |
| 8 | CAP-AUX-OIES | 1 | 0 | 0 | 1 |
| 9 | GRAND-POINT | 0 | 0 | 0 | 0 |
| 10 | CAP BRULE | 0 | 4 | 0 | 4 |
| 11 | ST. LAURENT | 1 | 0 | 0 | 1 |
| 13 | QUEBEC | 10 | 5 | 8 | 23 |
| 14 | ST. AUGUSTIN | 1 | 6 | 1 | 8 |
| 15 | DONNACONA | 1 | 5 | 0 | 6 |
| 16 | GRONDINES | 4 | 11 | 2 | 17 |
| 17 | BATISCAN | 2 | 11 | 0 | 13 |
| 19 | POINTE-DES-ORMES | 8 | 12 | 3 | 23 |
| 20 | YAMACHICHE | 4 | 5 | 0 | 9 |
| 21 | ILE DES BARQUES | 4 | 6 | 1 | 11 |
| 22 | TRACY | 0 | 4 | 0 | 4 |
| 24 | CAP ST. MICHEL | 0 | 0 | 0 | 0 |
| 25 | MONTREAL EST | 2 | 5 | 1 | 8 |
| Grand Total | | 41 | 80 | 16 | 137 |

Table 11. Comparison of Accident Rates by CIP Area (Summer)

| CIP Area | | | | | Total | | Breakdown by Damage Degree *** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Name | Summer Traffic** Count (95/96) | Length (nmi, rounded) | Traffic nmi (Count x nmi actual) | Accident (Count per 22.5 years) | Summer Accident RATE* | High Count per 22.5 years | High Summer RATE* | Medium Count per 22.5 years | Medium Summer RATE* | Low Count per 22.5 years | Low Summer RATE* |
| 5 | ESCOUMINS | 2,419 | 17 | 40394 | 2 | 0.22 | 0 | 0.00 | 0 | 0.00 | 2 | 0.22 |
| 6 | HAUT-FOND PRINCE | 2,454 | 13 | 32640 | 1 | 0.14 | 1 | 0.14 | 0 | 0.00 | 0 | 0.00 |
| 7 | ILE BLANCHE | 2,426 | 11 | 27411 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 0 | CAP AU SAUMON | 2,415 | 19 | 45157 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 8 | CAP-AUX-OIES | 2,428 | 21 | 50993 | 1 | 0.09 | 0 | 0.00 | 0 | 0.00 | 1 | 0.09 |
| 9 | GRAND-POINT | 2,423 | 16 | 38772 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 10 | CAP BRULE | 2,425 | 14 | 34674 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 11 | ST. LAURENT | 2,452 | 16 | 39226 | 1 | 0.11 | 0 | 0.00 | 0 | 0.00 | 1 | 0.11 |
| 13 | QUEBEC | 2,235 | 10 | 22127 | 11 | **2.21** | 0 | 0.00 | 5 | **1.00** | 4 | **0.80** |
| 14 | ST. AUGUSTIN | 2,258 | 12 | 26875 | 1 | 0.17 | 0 | **0.00** | 0 | 0.00 | 1 | 0.17 |
| 15 | DONNACONA | 2,258 | 14 | 30940 | 3 | 0.43 | 0 | 0.00 | 1 | 0.14 | 2 | 0.29 |
| 16 | GRONDINES | 2,260 | 14 | 30509 | 5 | **0.73** | 2 | **0.29** | 1 | 0.15 | 1 | **0.15** |
| 17 | BATISCAN | 2,269 | 16 | 36310 | 5 | 0.61 | 0 | 0.00 | 0 | 0.00 | 5 | **0.61** |
| 19 | POINTE-DES-ORMES | 2,152 | 15 | 31417 | 8 | **1.13** | 1 | **0.14** | 3 | **0.42** | 3 | **0.42** |
| 20 | YAMACHICHE | 2,168 | 10 | 22117 | 3 | 0.60 | 0 | 0.00 | 2 | **0.40** | 1 | 0.20 |
| 21 | ILE DES BARQUES | 2,170 | 14 | 31028 | 4 | 0.57 | 0 | 0.00 | 1 | 0.14 | 3 | 0.43 |
| 22 | TRACY | 2,032 | 12 | 25195 | 1 | 0.18 | 0 | 0.00 | 0 | 0.00 | 1 | 0.18 |
| 24 | CAP ST. MICHEL | 2,081 | 11 | 22893 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 25 | MONTREAL EST | 2,203 | 9 | 18947 | 2 | 0.47 | 0 | 0.00 | 0 | 0.00 | 2 | **0.47** |
| Grand Total | | | | 607626 | 48 | 0.35 | 4 | | 13 | | 27 | |
| CASUALTY TYPE | | | | | | | | | | | | |
| Collisions | | | | | 15 | | 0 | | 8 | | 5 | |
| Groundings | | | | | 26 | | 3 | | 1 | | 20 | |
| Strikings | | | | | 7 | | 1 | | 4 | | 2 | |
| Mean | | | | | | 0.40 | | 0.03 | | 0.12 | | 0.22 |
| Standard Deviation | | | | | | 0.54 | | 0.08 | | 0.25 | | 0.23 |
| Mean + 1 SD | | | | | | 0.94 | | 0.11 | | 0.37 | | 0.45 |

*e.g., for Escoumins: 2419 x 16.7 = 40394 vessel miles per summer. 2/22.5 = .09 accidents per summer or per 40394 nmi, or .22 accidents per 100000 nmi travelled. Accident data from 1/20/75 to 7/7/97.

** Includes all merchant vessels except for ferries for 6-month summers (95-96).

*** For 9 percent of the Set of 137 records, Damage Degree is "unknown". These records are included in the Grand Total only.

## Table 12. Comparison of Accident Rates by CIP Area (Winter)

| CIP Area | | | Total | | | | Breakdown by Damage Degree *** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Winter Traffic** | Length | Traffic nmi | Accident | Winter | High | | Medium | | Low | |
| # | Name | Count (95/96) | (nmi, rounded) | (Count x nmi actual) | (Count per 22.5 years) | Accident RATE* | Count per 22.5 years | Winter RATE* | Count per 22.5 years | Winter RATE* | Count per 22.5 years | Winter RATE* |
| 5 | ESCOUMINS | 2,438 | 17 | 40718 | 1 | 0.11 | 0 | 0.00 | 0 | 0.00 | 1 | 0.11 |
| 6 | HAUT-FOND PRINCE | 2,474 | 13 | 32902 | 1 | 0.14 | 1 | 0.14 | 0 | 0.00 | 0 | 0.00 |
| 7 | ILE BLANCHE | 2,445 | 11 | 27631 | 3 | 0.48 | 0 | 0.00 | 2 | 0.32 | 1 | 0.16 |
| 0 | CAP AU SAUMON | 2,434 | 19 | 45520 | 1 | 0.10 | 1 | 0.10 | 0 | 0.00 | 0 | 0.00 |
| 8 | CAP-AUX-OIES | 2,448 | 21 | 51403 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 9 | GRAND-POINT | 2,443 | 16 | 39084 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 10 | CAP BRULE | 2,444 | 14 | 34953 | 4 | 0.51 | 2 | 0.25 | 0 | 0.00 | 2 | 0.25 |
| 11 | SAINT-LAURENT | 2,471 | 16 | 39542 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 13 | QUEBEC | 2,253 | 10 | 22304 | 12 | 2.39 | 1 | 0.20 | 2 | 0.40 | 6 | 1.20 |
| 14 | SAINT-AUGUSTIN | 2,277 | 12 | 27091 | 7 | 1.15 | 4 | 0.66 | 3 | 0.49 | 0 | 0.00 |
| 15 | DONNACONA | 2,277 | 14 | 31189 | 3 | 0.43 | 0 | 0.00 | 1 | 0.14 | 1 | 0.14 |
| 16 | GRONDINES | 2,278 | 14 | 30754 | 12 | 1.73 | 3 | 0.43 | 2 | 0.29 | 7 | 1.01 |
| 17 | BATISCAN | 2,288 | 16 | 36602 | 8 | 0.97 | 2 | 0.24 | 1 | 0.12 | 5 | 0.61 |
| 19 | POINTE-DES-ORMES | 2,169 | 15 | 31669 | 15 | 2.11 | 4 | 0.56 | 4 | 0.56 | 6 | 0.84 |
| 20 | YAMACHICHE | 2,186 | 10 | 22294 | 6 | 1.20 | 2 | 0.40 | 2 | 0.40 | 2 | 0.40 |
| 21 | ILE DES BARQUES | 2,187 | 14 | 31277 | 7 | 0.99 | 0 | 0.00 | 1 | 0.14 | 4 | 0.57 |
| 22 | TRACY | 2,048 | 12 | 25397 | 3 | 0.52 | 0 | 0.00 | 0 | 0.00 | 3 | 0.52 |
| 24 | CAP SAINT-MICHEL | 2,098 | 11 | 23076 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| 25 | MONTREAL EST | 2,221 | 9 | 19099 | 6 | 1.40 | 2 | 0.47 | 0 | 0.00 | 3 | 0.70 |
| Grand Total | | | | 612506 | 89 | 0.65 | 22 | | 18 | | 41 | |
| CASUALTY TYPE | | | | | | | | | | | | |
| Collisions | | | | | 26 | | 4 | | 10 | | 7 | |
| Groundings | | | | | 54 | | 18 | | 5 | | 29 | |
| Strikings | | | | | 9 | | 0 | | 3 | | 5 | |
| Mean | | | | | | 0.75 | | 0.18 | | 0.15 | | 0.34 |
| Standard Deviation | | | | | | 0.75 | | 0.22 | | 0.20 | | 0.38 |
| Mean + 1 SD | | | | | | 1.50 | | 0.40 | | 0.35 | | 0.73 |

*e.g., for ESCOUMINS: 2438 x 16.7 = 40718 vessel miles per winter. 1/22.5 = .04 accidents per year or per 40718 nmi, or .11 accidents per 100000 nmi travelled. Accident data from 1/20/75 to 7/7/97.

** Includes all merchant vessels except for ferries for 6-month winters (95-96).

*** For 9 percent of the Set of 137 records, Damage Degree is "unknown". These records are included in the Grand Total only.

Table 13. Data for CW/MSD and Accident Rates Plotted in Figure 3

| | SUMMER | | WINTER | | TOTAL | |
|---|---|---|---|---|---|---|
| CIP # | CW/MSD (Median) | Acc. Rate (# acc./22.5 yr) | CW/MSD (Median) | Acc. Rate (# acc./22.5 yr) | CW/MSD (Avg. of Medians) | Acc. Rate (# acc./22.5 yr) |
| 6 | 3.00 | 0.14 (1) | 3.30 | 0.14 (1) | 3.20 | 0.14 (2) |
| 7 | 3.55 | 0.00 (0) | 4.10 | 0.48 (3) | 3.80 | 0.24 (3) |
| 10 | 1.24 | 0.00 (0) | 0.87 | 0.51 (4) | 1.10 | 0.26 (4) |
| 11 | 1.64 | 0.11 (1) | 1.28 | 0.00 (0) | 1.50 | 0.06 (1) |
| 19 | 1.21 | 1.13 (8) | 1.45 | 2.11 (15) | 1.30 | 1.62 (23) |
| 20 | 1.06 | 0.6 (3) | 1.01 | 1.20 (6) | 1.03 | 0.90 (9) |

* Accident Rate is per 100,000 vessel nmi.

# Appendix B: Working Tables and Figures

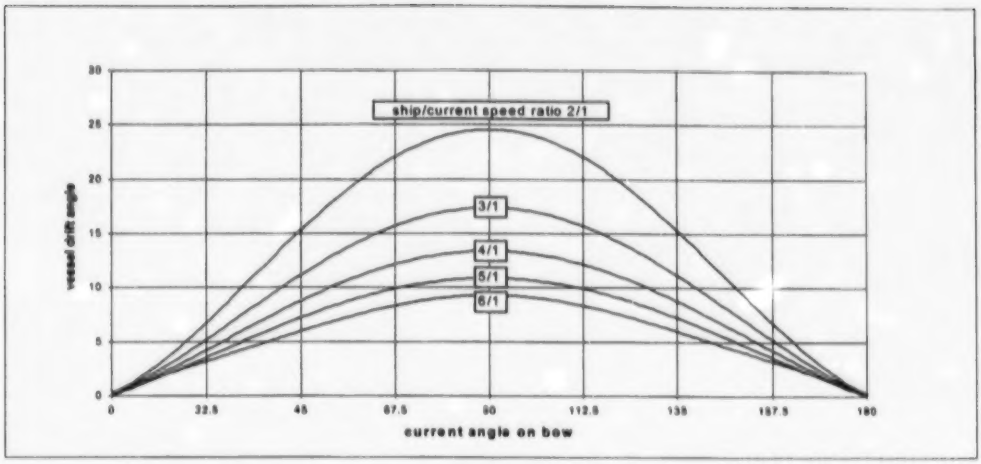


**Figure 1. Vessel Drift Angle due to Current**

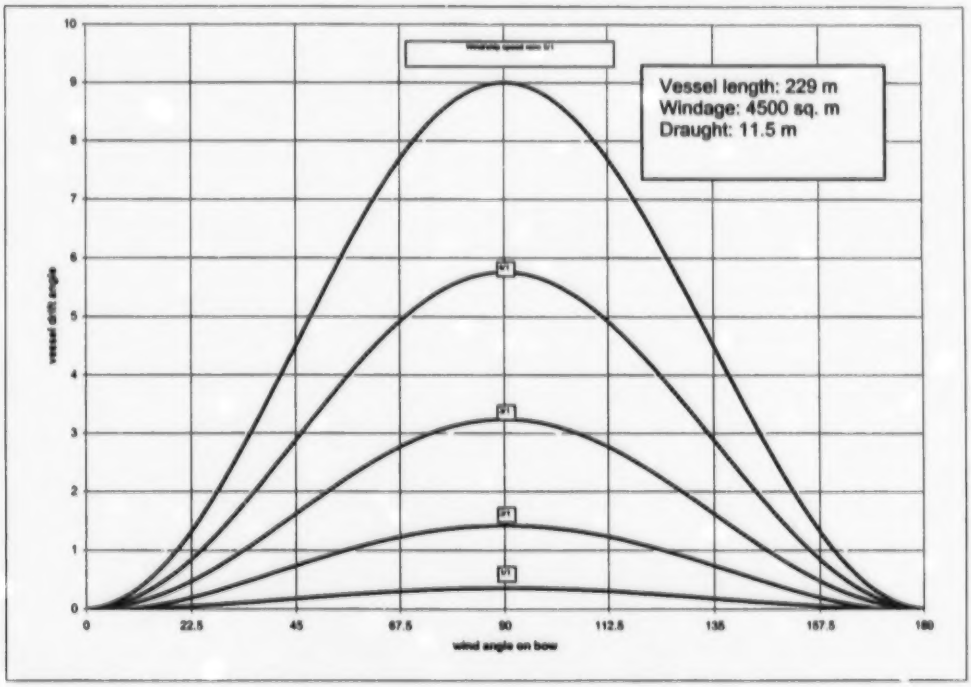


**Figure 2. Vessel Drift Angle due to Wind (length 229 m, windage 4500 sq.m., draught 11.5 m)**

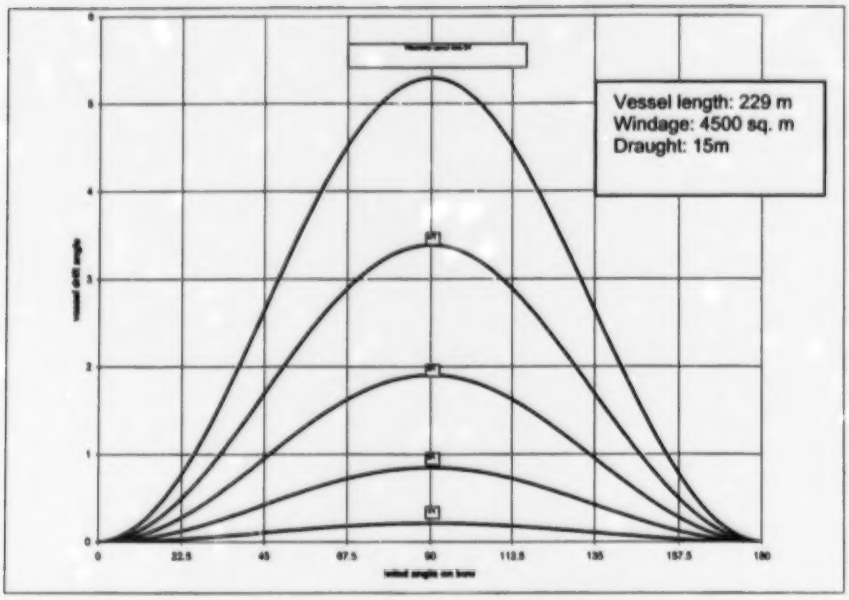


**Figure 3. Vessel Drift Angle due to Wind (length 229 m, windage 4500 sq.m., draught 15 m)**

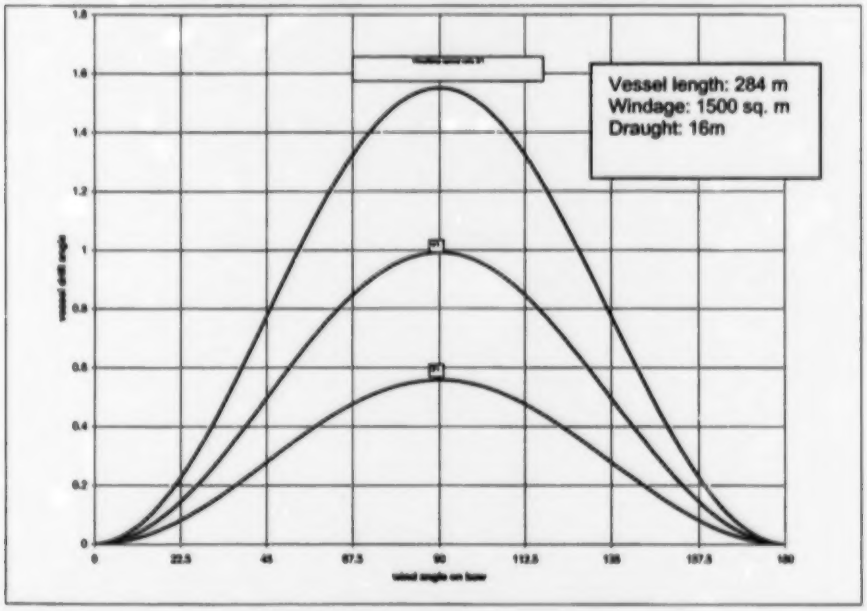


**Figure 4. Vessel Drift Angle due to Wind (length 284 m, windage 1500 sq.m., draught 16 m)**

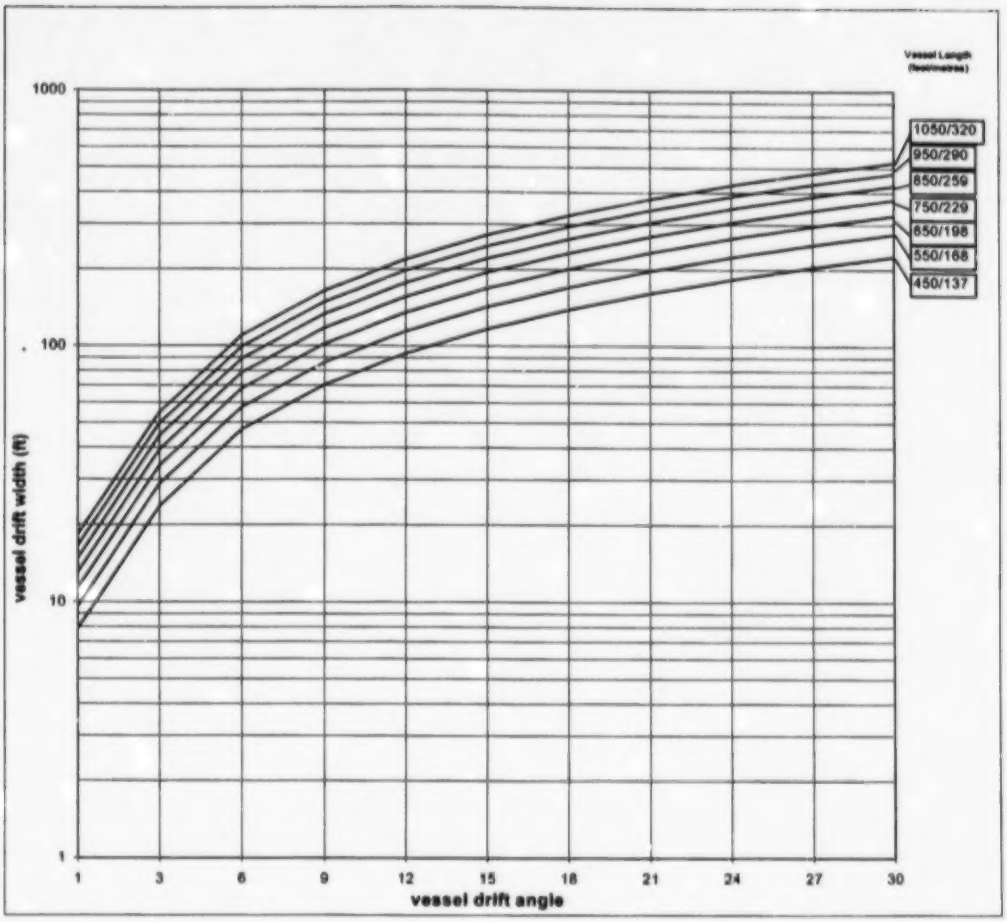


**Figure 5. Vessel Drift Width per Drift Angle**

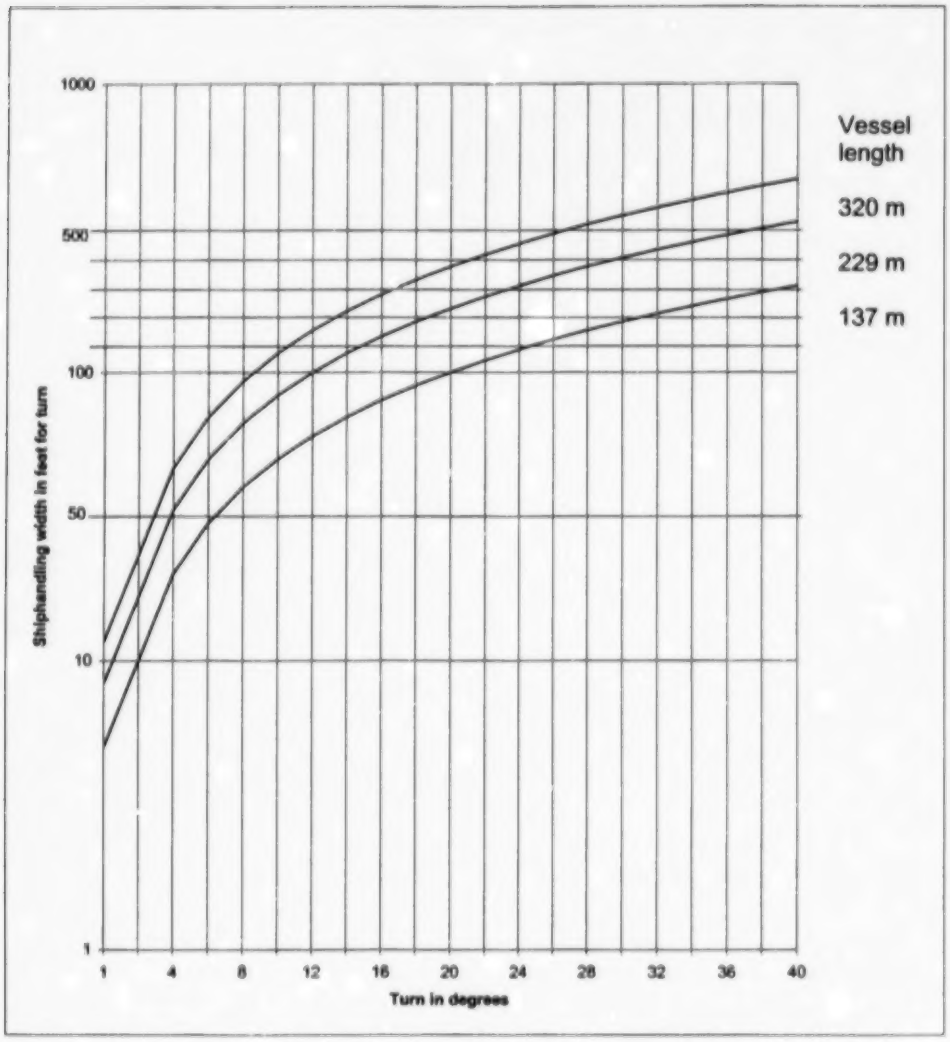


**Figure 6. Turn and Straight Widths**

Note: 1. Add width for a straight track section to shiphandling width for turn
2. Shiphandling width for straight track is 0.8 x the vessel's beam
3. For turns in steps, use either 5 or 10 degrees

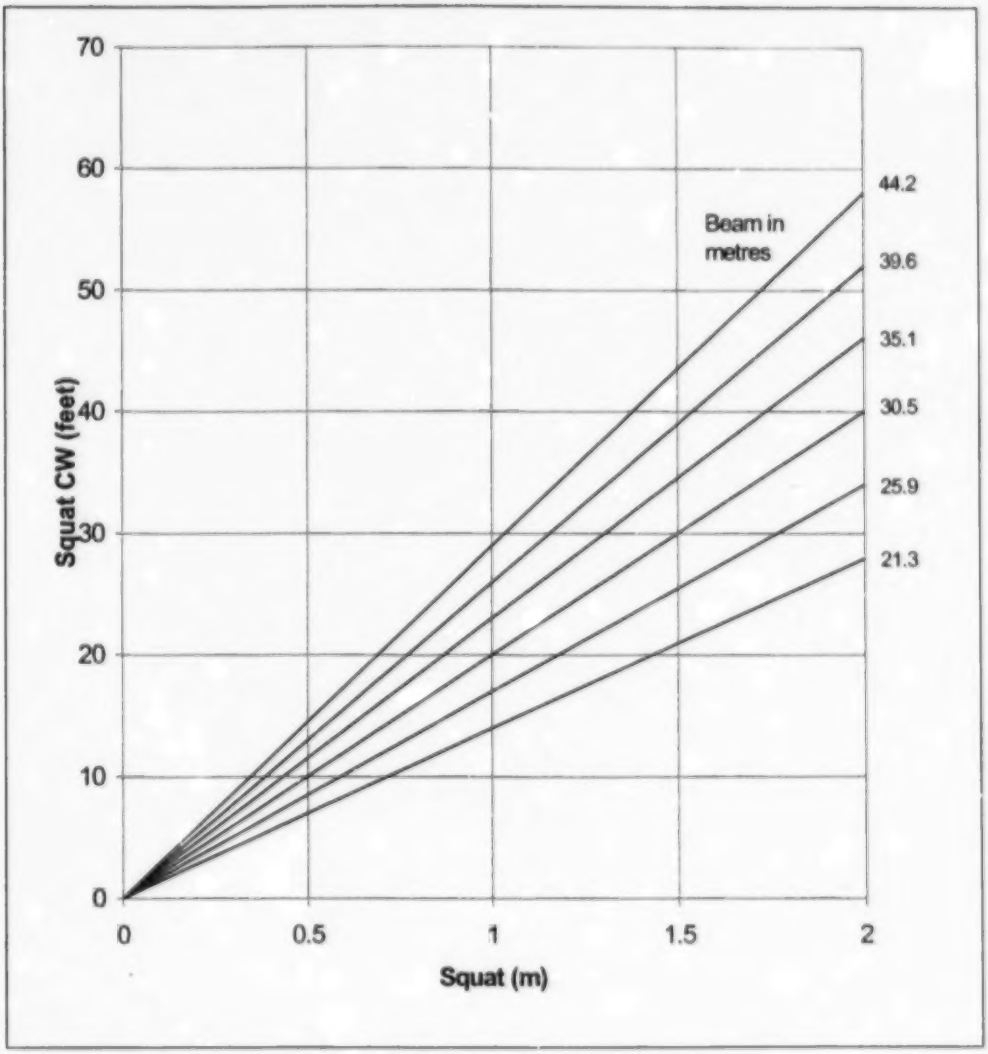


**Figure 7. Channel Width in Feet due to Squat (m)**

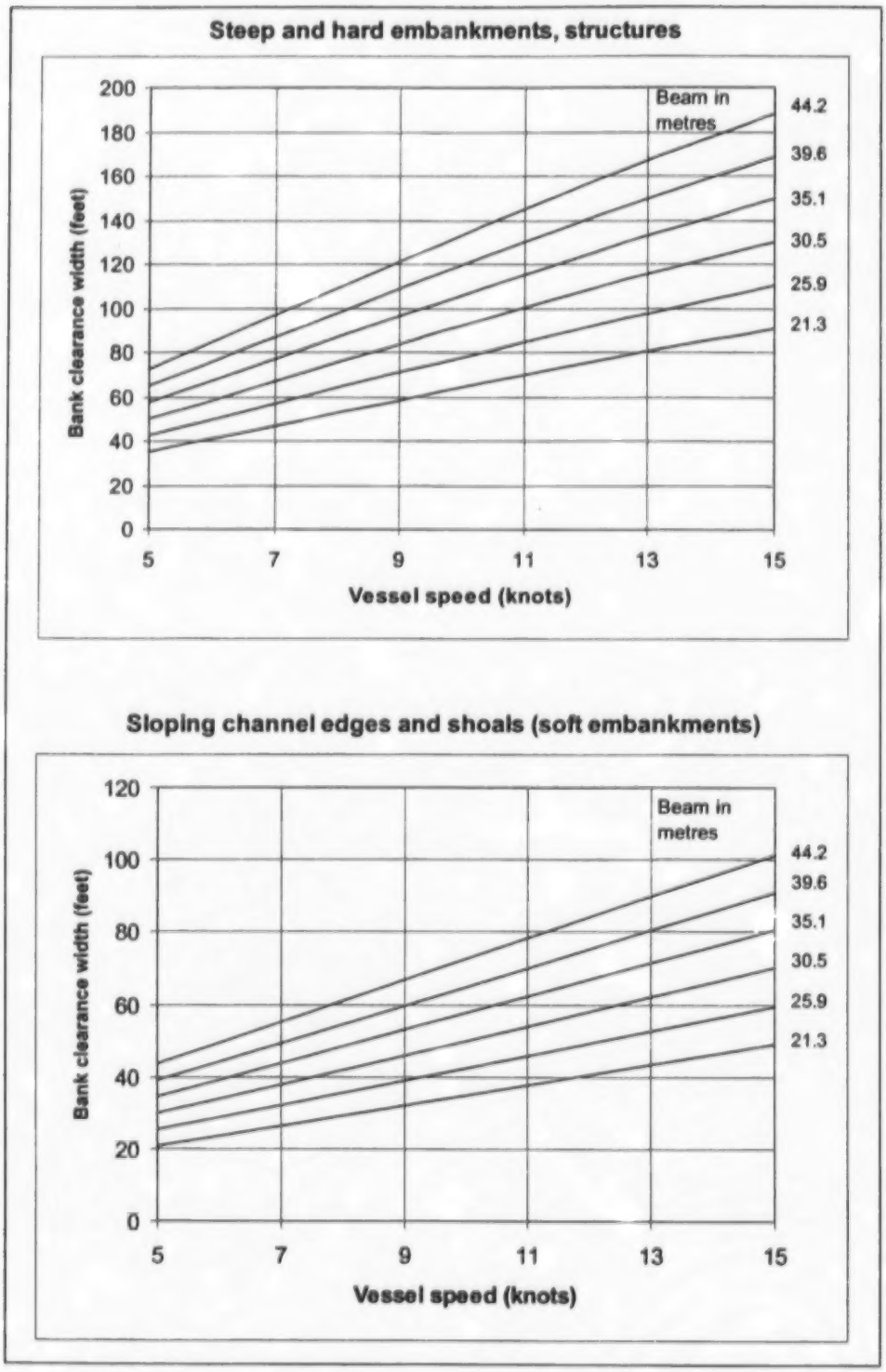


**Figure 8. Bank Clearance (One Side)**

| Supprimer calcule | Donnée | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | RM Saint-Jean | | | | ☐ | ☐ | 354 | 130 | 307 | 269 | 100 | 1500 | 1250 | 761 | 1.19 | 1.97 | |
| 2 | Saint-Jean à K-135 | | | | ☐ | ☐ | 356 | 136 | 101 | 113 | 50 | 1500 | 896 | 505 | 1.67 | 2.97 | |
| 3 | K-135 à K-119 | | | | ☐ | ☐ | 351 | 132 | 101 | 113 | 50 | 1500 | 891 | 502 | 1.68 | 2.99 | |
| 4 | K-119 à K-107 | | | | ☐ | ☐ | 376 | 143 | 101 | 113 | 50 | 1000 | 926 | 527 | 1.08 | 1.90 | |
| 5 | RM K-106 | | | | ☐ | ☐ | 383 | 148 | 199 | 187 | 75 | 1000 | 1074 | 657 | 0.93 | 1.52 | |
| 6 | K-106 À Cap Brûlé | | | | ☐ | ☐ | 372 | 164 | 101 | 113 | 50 | 1000 | 943 | 522 | 1.06 | 1.91 | |
| 7 | RM K-100 | | | | ☐ | ☐ | 334 | 133 | 200 | 186 | 75 | 1000 | 1010 | 609 | 0.99 | 1.64 | |
| 8 | Cap Brûlé à K-91 | | | | ☐ | ☐ | 343 | 125 | 101 | 113 | 50 | 1000 | 876 | 494 | 1.14 | 2.02 | |
| 9 | RM K-91 | | | | ☐ | ☐ | 343 | 125 | 181 | 171 | 75 | 1200 | 996 | 600 | 1.21 | 2.00 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 9. Traverse du Nord: Passager & Conteneur, Aides Exist Été, Vent NW 25/30, Bonne Visibilité**

| Supprimer calculs | Données | Exécuter calculs | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | Pointe d'Alliance à Cap Rouge | | | | ☐ | ☐ | 170 | 116 | 131 | 117 | 200 | 1000 | 1010 | 502 | 0.99 | 1.99 | |
| 2 | RM K100 | | | | ☐ | ☐ | 160 | 110 | 247 | 168 | 250 | 1000 | 1206 | 658 | 0.83 | 1.52 | |
| 3 | Cap Brûlé à K-108 | | | | ☐ | ☐ | 160 | 120 | 136 | 117 | 200 | 1000 | 1027 | 515 | 0.97 | 1.94 | |
| 4 | RM K-108 | | | | ☐ | ☐ | 178 | 129 | 333 | 198 | 250 | 1000 | 1337 | 761 | 0.75 | 1.31 | |
| 5 | K-107 à K-119 | | | | ☐ | ☐ | 172 | 123 | 210 | 122 | 225 | 1000 | 1149 | 607 | 0.87 | 1.65 | |
| 6 | K-119 à K-135 | | | | ☐ | ☐ | 161 | 111 | 203 | 115 | 200 | 1000 | 1068 | 564 | 0.94 | 1.77 | |
| 7 | RM K-136 | | | | ☐ | ☐ | 108 | 116 | 226 | 174 | 250 | 1500 | 1182 | 643 | 1.27 | 2.33 | |
| 8 | Saint-Jean | | | | ☐ | ☐ | 173 | 118 | 121 | 109 | 200 | 1500 | 1007 | 496 | 1.49 | 3.03 | |
| 9 | RM Rivière Lafleur | | | | ☐ | ☐ | 173 | 118 | 279 | 213 | 250 | 1500 | 1284 | 702 | 1.17 | 2.14 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 10. Traverse du Nord: Pétrolier & Conteneur, Hiver, 2 Miles Vis., Aides Existantes, Marée Haute**

| Supprimer calcule | Données | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | Points d'Alliance à Cap Rouge | | | | ☐ | ☐ | 170 | 115 | 125 | 117 | 225 | 1000 | 1056 | 520 | 0.95 | 1.92 | |
| 2 | RM K100 | | | | ☐ | ☐ | 160 | 109 | 245 | 189 | 125 | 1000 | 964 | 530 | 1.05 | 1.89 | |
| 3 | Cap Brûlé à K-106 | | | | ☐ | ☐ | 180 | 120 | 125 | 117 | 225 | 1000 | 1071 | 530 | 0.93 | 1.89 | |
| 4 | RM K-108 | | | | ☐ | ☐ | 178 | 125 | 320 | 190 | 100 | 1000 | 1013 | 598 | 0.99 | 1.67 | |
| 5 | K-107 à K-119 | | | | ☐ | ☐ | 172 | 120 | 200 | 117 | 200 | 1000 | 1088 | 572 | 0.92 | 1.75 | |
| 6 | K-119 à K-136 | | | | ☐ | ☐ | 161 | 110 | 200 | 117 | 175 | 1000 | 1017 | 536 | 0.98 | 1.87 | |
| 7 | RM K-136 | | | | ☐ | ☐ | 168 | 114 | 219 | 174 | 225 | 1500 | 1129 | 612 | 1.33 | 2.45 | |
| 8 | Saint-Jean | | | | ☐ | ☐ | 173 | 117 | 113 | 107 | 225 | 1500 | 1051 | 511 | 1.43 | 2.93 | |
| 9 | RM Rivière Lafleur | | | | ☐ | ☐ | 173 | 117 | 270 | 211 | 275 | 1500 | 1322 | 719 | 1.13 | 2.09 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 11. Traverse du Nord: Pétrolier & Conteneur, Hiver, 2 Miles Vis., Aides AASL, Marée Haute**

| Supprimer calculs | Données | Exécuter calculs | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | Pointe d'Alliance à Cap Rouge | | | | ☐ | ☐ | 170 | 116 | 125 | 86 | 150 | 1000 | 891 | 446 | 1.12 | 2.24 | |
| 2 | RM K100 | | | | ☐ | ☐ | 160 | 109 | 245 | 177 | 75 | 1000 | 842 | 481 | 1.19 | 2.09 | |
| 3 | Cap Brûlé à K-108 | | | | ☐ | ☐ | 160 | 122 | 125 | 86 | 100 | 1000 | 807 | 406 | 1.24 | 2.47 | |
| 4 | RM K-108 | | | | ☐ | ☐ | 178 | 130 | 321 | 176 | 75 | 1000 | 955 | 573 | 1.05 | 1.74 | |
| 5 | K-107 à K-119 | | | | ☐ | ☐ | 171 | 124 | 201 | 86 | 100 | 1000 | 876 | 472 | 1.14 | 2.12 | |
| 6 | K-119 à K-136 | | | | ☐ | ☐ | 161 | 110 | 201 | 86 | 100 | 1000 | 861 | 462 | 1.16 | 2.17 | |
| 7 | RM K-136 | | | | ☐ | ☐ | 168 | 115 | 220 | 160 | 125 | 1500 | 922 | 513 | 1.63 | 2.92 | |
| 8 | Saint-Jean | | | | ☐ | ☐ | 173 | 119 | 113 | 79 | 200 | 1500 | 989 | 486 | 1.52 | 3.09 | |
| 9 | RM Rivière Lafleur | | | | ☐ | ☐ | 173 | 119 | 271 | 201 | 125 | 1500 | 1016 | 569 | 1.48 | 2.64 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 12. Traverse du Nord: Pétrolier et Ferbec, Été, Montant, 2 Miles Vis., Aides Exist., Marée Haute, Nuit**

| Supprimer calcule | Données | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | RM - C-63 | | | | ☐ | ☐ | 119 | 119 | 139 | 139 | 75 | 1020 | 727 | 332 | 1.40 | 3.07 | |
| 2 | Pont Laviolette | | | | ☐ | ☐ | 145 | 145 | 234 | 234 | 75 | 750 | 969 | 455 | 0.77 | 1.65 | |
| 3 | Pt-des-Ormes - St-Francois | | | | ☐ | ☐ | 126 | 126 | 97 | 97 | 225 | 1200 | 999 | 448 | 1.20 | 2.68 | |
| 4 | Courbe Nicolet | | | | ☐ | ☐ | 136 | 136 | 189 | 189 | 75 | 1100 | 961 | 400 | 1.29 | 2.75 | |
| 5 | Courbe Pointe du Lac | | | | ☐ | ☐ | 149 | 149 | 189 | 189 | 150 | 1100 | 1037 | 488 | 1.06 | 2.26 | |
| 6 | Course Pointe du Lac | | | | ☐ | ☐ | 127 | 127 | 98 | 98 | 175 | 800 | 903 | 401 | 0.89 | 2.00 | |
| 7 | Course Pointe du Lac | | | | ☐ | ☐ | 124 | 124 | 149 | 149 | 100 | 800 | 847 | 373 | 0.94 | 2.14 | |
| 8 | RM 8-54 | | | | ☐ | ☐ | 124 | 124 | 191 | 191 | 75 | 800 | 839 | 389 | 0.95 | 2.06 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
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**Figure 13. Trois–Rivières à Yamachiche: 2 Conteneurs, Aides AASL, Été, Montant, 1 Mile Vis., Nuit**

| Supprimer calculs | Ouvrir | Exécuter calculs | Facteurs humains | | | | Paramètres DMS | | | | | DMB | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMB: Trafic bi-directionnel | DMB: Trafic uni-directionnel | $\frac{LC}{DMB}$ Trafic bi-directionnel | $\frac{LC}{DMB}$ Trafic uni-directionnel | NOTES |
| 1 | RM Yamachiche | | | | ☐ | ☐ | 89 | 67 | 96 | 129 | 175 | 800 | 949 | 360 | 0.94 | 2.22 | |
| 2 | S-61 a S-43 | | | | ☐ | ☐ | 76 | 66 | 103 | 52 | 175 | 800 | 779 | 353 | 1.03 | 2.26 | |
| 3 | S-43 a Courbe Pointe du Lac | | | | ☐ | ☐ | 78 | 66 | 80 | 52 | 200 | 800 | 788 | 338 | 1.01 | 2.37 | |
| 4 | Courbe Pointe du Lac | | | | ☐ | ☐ | 101 | 72 | 96 | 67 | 175 | 1100 | 906 | 372 | 1.37 | 2.96 | |
| 5 | Courbe Nicolet | | | | ☐ | ☐ | 113 | 94 | 139 | 100 | 175 | 1100 | 914 | 426 | 1.20 | 2.58 | |
| 6 | Pt-des-Ormes - St-Francois | | | | ☐ | ☐ | 77 | 66 | 80 | 52 | 200 | 1200 | 788 | 337 | 1.52 | 3.56 | |
| 7 | Pont Laviolette | | | | ☐ | ☐ | 83 | 69 | 175 | 128 | 175 | 750 | 913 | 433 | 0.82 | 1.73 | |
| 8 | RM - C-63 | | | | ☐ | ☐ | 88 | 63 | 96 | 67 | 175 | 1020 | 782 | 359 | 1.30 | 2.84 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
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**Figure 14. Trois–Rivières à Yamachiche: Cicero & CTMA, Début Hiver, 0 Mile Vis., Tempête Neige, Aides Exist**

| Supprimer calculs | Données | Exécuter calculs | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | RM Yamachiche | | | | ☐ | ☐ | 89 | 67 | 96 | 128 | 226 | 800 | 949 | 410 | 0.84 | 1.95 | |
| 2 | S-61 a S-43 | | | | ☐ | ☐ | 76 | 66 | 103 | 62 | 175 | 900 | 779 | 353 | 1.03 | 2.26 | |
| 3 | S-43 a Courbe Pointe du Lac | | | | ☐ | ☐ | 79 | 66 | 80 | 62 | 250 | 800 | 889 | 388 | 0.90 | 2.06 | |
| 4 | Courbe Pointe du Lac | | | | ☐ | ☐ | 101 | 72 | 96 | 67 | 226 | 1100 | 906 | 422 | 1.22 | 2.60 | |
| 5 | Courbe Nicolet | | | | ☐ | ☐ | 113 | 94 | 139 | 100 | 226 | 1100 | 1014 | 476 | 1.08 | 2.31 | |
| 6 | Pt-des-Ormes - St-Francois | | | | ☐ | ☐ | 77 | 66 | 80 | 62 | 250 | 1200 | 888 | 387 | 1.35 | 3.10 | |
| 7 | Pont Laviolette | | | | ☐ | ☐ | 83 | 69 | 175 | 129 | 226 | 750 | 1013 | 483 | 0.74 | 1.55 | |
| 8 | RM - C-63 | | | | ☑ | ☑ | 89 | 63 | 96 | 67 | 175 | 1020 | 782 | 359 | 1.30 | 2.84 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
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**Figure 15. Trois–Rivières à Yamachiche: Cicero & CTMA, Début Hiver, 0 Mile Vis., Tempête Neige, Aides AASL**

| Supprimer calcule | Données | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | RM - C-83 | | | | ☐ | ☐ | 67 | 107 | 98 | 148 | 50 | 1020 | 691 | 202 | 1.48 | 5.05 | |
| 2 | Pont Laviolette | | | | ☐ | ☐ | 83 | 134 | 156 | 275 | 75 | 750 | 979 | 314 | 0.77 | 2.39 | |
| 3 | Pt-des-Ormes - St-Francois | | | | ☐ | ☐ | 68 | 110 | 56 | 107 | 100 | 1200 | 759 | 223 | 1.58 | 5.38 | |
| 4 | Courbe Nicolet | | | | ☐ | ☐ | 75 | 118 | 114 | 214 | 50 | 1100 | 806 | 239 | 1.37 | 4.61 | |
| 5 | Courbe Pointe du Lac | | | | ☐ | ☐ | 79 | 130 | 123 | 214 | 50 | 1100 | 830 | 253 | 1.32 | 4.35 | |
| 6 | Course Pointe du Lac | | | | ☐ | ☐ | 68 | 110 | 55 | 110 | 50 | 800 | 661 | 173 | 1.21 | 4.63 | |
| 7 | Course Pointe du Lac | | | | ☐ | ☐ | 67 | 107 | 92 | 176 | 50 | 800 | 760 | 209 | 1.05 | 3.83 | |
| 8 | RM S-54 | | | | ☐ | ☐ | 67 | 107 | 123 | 217 | 50 | 800 | 796 | 240 | 1.00 | 3.34 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
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**Figure 16. Trois–Rivières à Yamachiche: Pétrolier & Conteneur, Aides Exist., Sept., Mont., 10 Miles vis., Marée 1m**

| Supprimer calcule | Données | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | |
| 1 | RM - C-53 | | | | ☐ | ☐ | 119 | 119 | 139 | 139 | 75 | 1020 | 727 | 332 | 1.40 | 3.07 | |
| 2 | Pont Laviolette | | | | ☐ | ☐ | 145 | 145 | 234 | 234 | 75 | 750 | 969 | 455 | 0.77 | 1.65 | |
| 3 | Pt-des-Ormes - St-Francois | | | | ☐ | ☐ | 126 | 126 | 97 | 97 | 100 | 1200 | 749 | 323 | 1.60 | 3.72 | |
| 4 | Courbe Nicolet | | | | ☐ | ☐ | 136 | 136 | 189 | 189 | 75 | 1100 | 861 | 400 | 1.28 | 2.75 | |
| 5 | Courbe Pointe du Lac | | | | ☐ | ☐ | 149 | 149 | 189 | 189 | 150 | 1100 | 1037 | 489 | 1.06 | 2.25 | |
| 6 | Course Pointe du Lac | | | | ☐ | ☐ | 127 | 127 | 98 | 98 | 100 | 800 | 653 | 326 | 1.23 | 2.46 | |
| 7 | Course Pointe du Lac | | | | ☐ | ☐ | 124 | 124 | 149 | 149 | 100 | 800 | 747 | 373 | 1.07 | 2.14 | |
| 8 | RM 8-54 | | | | ☐ | ☐ | 124 | 124 | 191 | 191 | 75 | 800 | 839 | 389 | 0.95 | 2.06 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 17. Trois–Rivières à Yamachiche: Conteneurs, Aides Existantes, Été, Montant, 1 Mile Vis., Nuit**

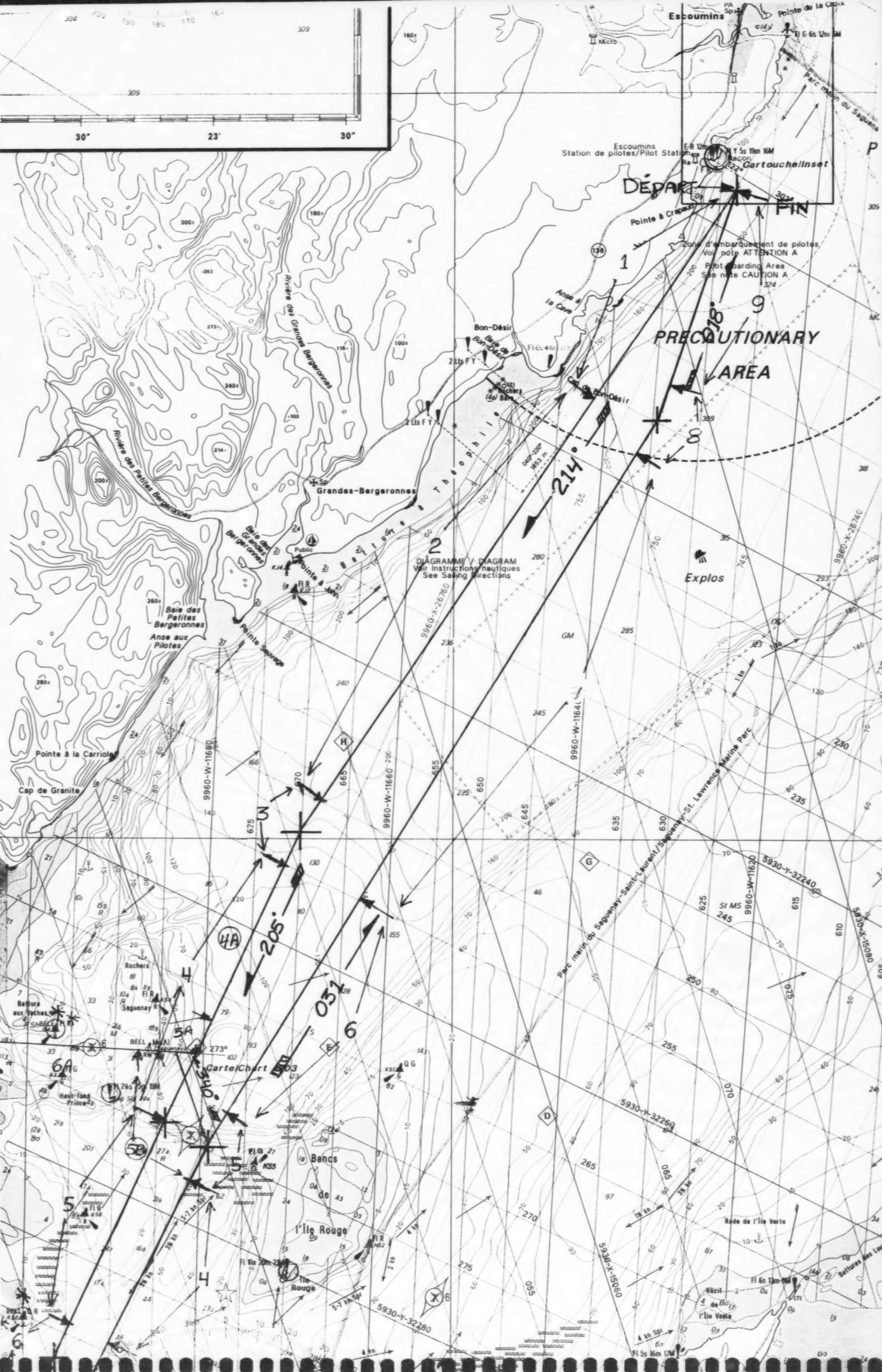
| Supprimer calcule | Données | Exécuter calcule | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | Escoumins - Bon Désir | | | | ☐ | ☐ | 134 | 134 | 86 | 86 | 200 | 3000 | - | 421 | - | 7.13 | |
| 2 | Bon Désir - Bergeronnes | | | | ☐ | ☐ | 114 | 114 | 86 | 86 | 225 | 6000 | - | 426 | - | 14.10 | |
| 3 | RM Pointe Sauvage | | | | ☐ | ☐ | 223 | 223 | 160 | 160 | 547 | 6000 | - | 931 | - | 6.44 | |
| 4 | Pointe Carlole - HFP | | | | ☐ | ☐ | 196 | 196 | 89 | 89 | 547 | 3000 | - | 832 | - | 3.61 | |
| 5 | HFP - Points Alouettes | | | | ☐ | ☐ | 169 | 169 | 101 | 101 | 547 | 3000 | - | 918 | - | 3.87 | |
| 6 | RM Pointe Alouettes | | | | ☐ | ☐ | 193 | 193 | 220 | 220 | 547 | 3000 | - | 961 | - | 3.12 | |
| 7 | Batture aux Alouettes | | | | ☐ | ☐ | 122 | 122 | 94 | 94 | 547 | 6000 | - | 763 | - | 7.87 | |
| 8 | RM Île du Chafaud | | | | ☐ | ☐ | 137 | 137 | 130 | 130 | 547 | 6000 | - | 815 | - | 7.37 | |
| 9 | Île Chafaud - Cap Chien | | | | ☐ | ☐ | 131 | 131 | 90 | 90 | 547 | 6000 | - | 758 | - | 7.91 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

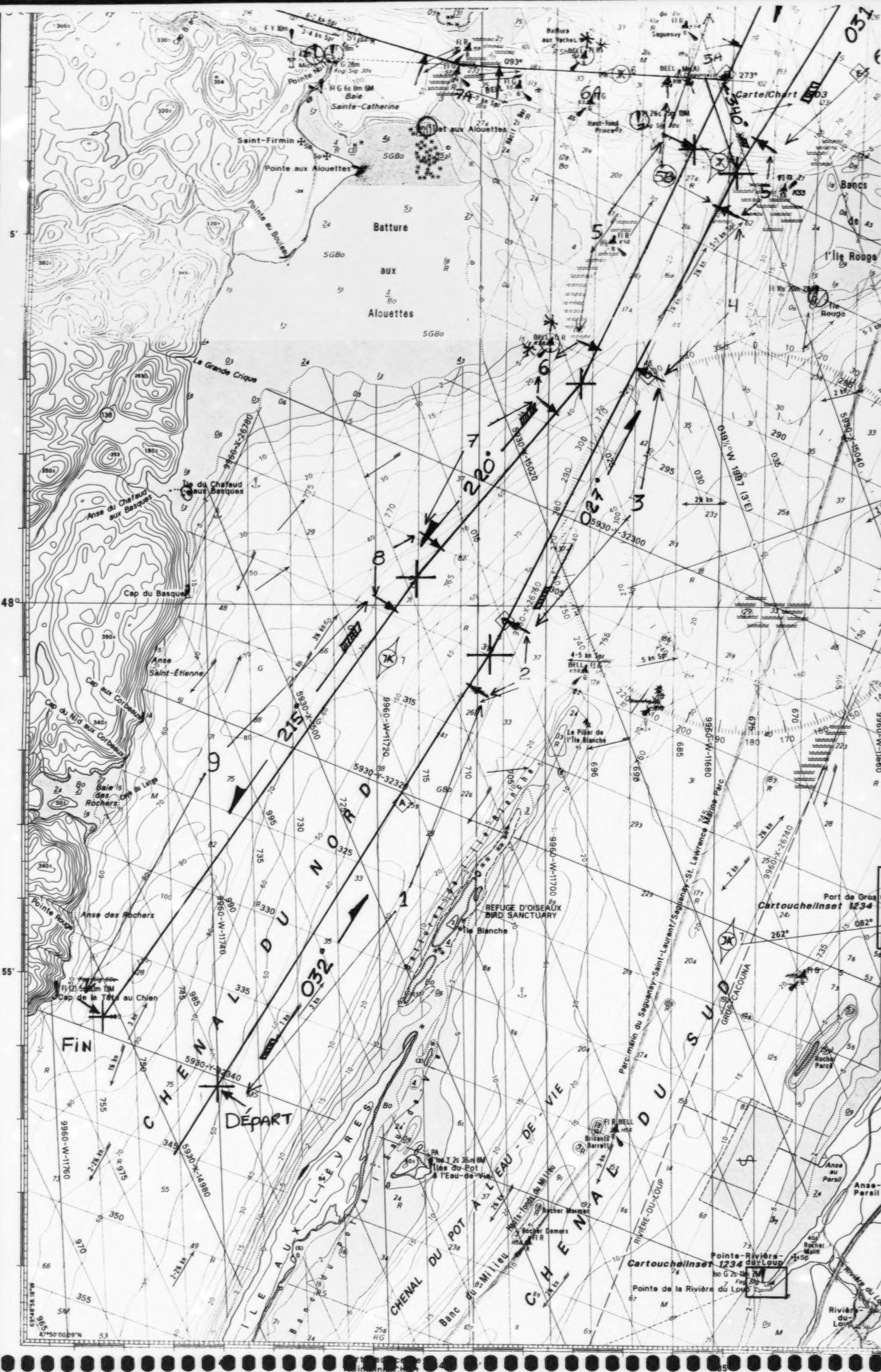
**Figure 18. Entrée du Saguenay: 2 Conteneurs, Hiver, Montant, 0 Mile Vis., Neige, Maree Bais., Aides Exist., Glace**

| Supprimer calculs | Données | Exécuter calculs | Facteurs humains | | | | Paramètres DMS | | | | | DMS | | | Mesure de sécurité | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nombre | Nom de la section | | Trafic élevé? | Accidents? | Charge de travail élevée? | Fatigue? | LC - Physique (navire de référence) | LC - Physique (navire rencontré) | LC - Manoeuvre du navire de référence | LC - Manoeuvre du navire rencontré | LC - Qualité de positionnement | LC - Largeur du chenal | DMS: Trafic bi-directionnel | DMS: Trafic uni-directionnel | $\frac{LC}{DMS}$ Trafic bi-directionnel | $\frac{LC}{DMS}$ Trafic uni-directionnel | NOTES |
| 1 | Escoumins - Bon Désir | | | | ☐ | ☐ | 165 | 165 | 98 | 97 | 274 | 3000 | 1072 | 537 | 2.80 | 5.59 | |
| 2 | Bon Désir - Bergeronnes | | | | ☐ | ☐ | 195 | 195 | 98 | 97 | 547 | 6000 | 1660 | 830 | 3.62 | 7.23 | |
| 3 | RM Pointe Sauvage | | | | ☐ | ☐ | 165 | 165 | 218 | 217 | 547 | 6000 | 1860 | 930 | 3.23 | 6.45 | |
| 4 | Pointe Carlole - HFP | | | | ☐ | ☐ | 195 | 195 | 100 | 99 | 547 | 3000 | 1682 | 842 | 1.78 | 3.56 | |
| 5 | HFP - Pointe Alouettes | | | | ☐ | ☐ | 157 | 157 | 111 | 106 | 547 | 3000 | 1626 | 815 | 1.84 | 3.68 | |
| 6 | RM Pointe Alouettes | | | | ☐ | ☐ | 305 | 305 | 288 | 284 | 547 | 3000 | 2276 | 1140 | 1.32 | 2.63 | |
| 7 | Batture aux Alouettes | | | | ☐ | ☐ | 271 | 271 | 105 | 102 | 547 | 6000 | 1842 | 922 | 3.26 | 6.50 | |
| 8 | RM Île du Chafaud | | | | ☐ | ☐ | 172 | 172 | 180 | 179 | 547 | 6000 | 1798 | 899 | 3 | 6.67 | |
| 9 | Île Chafaud - Cap Chien | | | | ☐ | ☐ | 157 | 157 | 101 | 99 | 547 | 6000 | 1609 | 805 | 4 | 7.45 | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | ☐ | ☐ | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure 19. Entrée du Saguenay: 2 Pétroliers, Été, Montant, 0 Mile Visibilité, Aides Existantes, Marée Haute**

# Appendix C: Passage Planning Charts


DÉPART
FIN
Escoumins
Escoumins
Station de pilotes/Pilot Station
Cartouche/Inset
Pointe à Crapaud
Zone d'embarquement de pilotes
Voir note ATTENTION A
Pilot Boarding Area
See note CAUTION A
PRECAUTIONARY AREA
Bon-Désir
Baie de Bon-Désir
Anse à la Cave
Rivière des Grandes Bergeronnes
Rivière des Petites Bergeronnes
Grandes-Bergeronnes
Baie des Grandes Bergeronnes
Baie des Petites Bergeronnes
Anse aux Pilotes
Pointe Sayenne
Pointe à la Carriole
Cap de Granite
DIAGRAMME / DIAGRAM
Voir instructions nautiques
See Sailing Directions
Explos
Parc marin du Saguenay-Saint-Laurent/Saguenay-St. Lawrence Marine Park
Cartel/Chart 1003
Bancs de l'Île Rouge
Île Rouge
Rade de l'Île Verte
Récif de l'Île Verte
214°
205°
031°
340°
9960-X-26760
9960-X-26740
9960-W-11660
9960-W-11641
9960-W-11620
5930-Y-32240
5930-Y-32260
5930-Y-32280
5930-X-15080
5930-X-15060
30°
23'
30°


CHENAL DU NORD
032°
CHENAL DU SUD
215°
220°
027°
340°
DÉPART
FIN
Cap de la Tête au Chien
Pointe Rouge
Anse des Rochers
Baie des Rochers
Cap aux Corbeaux
Cap du Nid aux Corbeaux
Anse Saint-Étienne
Cap du Basque
Anse du Chafaud aux Basques
Ile du Chafaud aux Basques
Le Grande Crique
Pointe au Boulet
Batture aux Alouettes
Saint-Firmin
Pointe aux Alouettes
Baie Sainte-Catherine
Pointe Noire
Ilet aux Alouettes
Batture aux Vaches
Pointe au Saguenay
Cartel/Chart 1303
Bancs de l'Ile Rouge
Ile Rouge
Haut-fond Prince
REFUGE D'OISEAUX BIRD SANCTUARY
Ile Blanche
Le Pilier de l'Ile Blanche
Ile aux Lièvres
Banc du Pot à l'Eau-de-Vie
CHENAL DU POT A L'EAU-DE-VIE
Banc du Milieu
Rocher Maman
Rocher Demers
Rocher Marin
Rocher Parcs
Parc marin du Saguenay-Saint-Laurent/Saguenay-St. Lawrence Marine Park
GRÈS CACOUNA
RIVIÈRE-DU-LOUP
Cartouche/Inset 1234
Pointe-Rivière-du-Loup
Pointe de la Rivière du Loup
Anse-Persil
Rivière-du-Loup
Port de Gros
Cartouche/Inset 1234
Fl (2) 5s 35m 5M
Cap de la Tête au Chien
Fl G 2s 35m 6M
Iles du Pot à l'Eau-de-Vie
Fl R Bell
Brisants Barrault
Fl R 4s
Fl G 4s
Fl R 2s
Fl G 2s
Fl R 6s 6m 6M
Baie Sainte-Catherine
Fl G 6s 6m 6M
Fl Y 4s 10m 5M
Fl Y 2s 35m 6M
Fl G 2s 35m 6M
Fl R 6s 6m 6M
Fl G 6s 6m 6M
Fl R 2s
Fl G 2s
Fl R 4s
Fl G 4s
Fl R Bell
Fl R Bell
Fl R 2s
Fl G 2s
Fl R 4s
Fl G 4s
Fl R 6s 6m 6M
Fl G 6s 6m 6M

ÎLE D'ORLÉANS

CHENAL DU NORD

CHENAL DU SUD

TRAVERSE DU CHENAL

Les Caps

Variation W 1999 (2'E)

Pointe Dauphine

Pointe Bellechasse

Pointe Pennault

Anse à Laverdière

Pointe à Blaye

Pointe Saint-Jean

Saint-Jean

Racon

Pointe Saint-Michel

Pointe Samson

Pointe à Labrecque

Saint-Michel

Pointe de La Durantaye

Banc de Saint-Vallier

REFUGE D'OISEAUX
BIRD SANCTUARY

Anse de Saint-Vallier

Saint-Vallier

Pointe de Saint-Vallier

Mares des

Ruisseau Bellechasse

Rivière Boyer

Rivière

Banc de l'Île Madame

Île Madame

Rocher Pointu
Fl Y 6s 13m 6M

Île de Bellechasse

Anse de Bellechasse

Pointe Rouge

Pointe de Berthier Est

Anse de Berthier

Pointe Verte

Trou de Berthier

Berthier-sur-Mer

Ruisseau Corriveau

ROUTE TRANSCANADIENNE / TRANS-CANADA HIGHWAY

Rivière

Saint-François-de-Montmagny

En raison d
près des b
peuvent êt
meilleur ch
(L.F.1888-188
centre du ch

## COURANTS DE MARÉE

Les directions et les vitesses approximatives de courants de marée, aux positions marquées avec des lettres, sont fournies dans le tableau et sont basées sur la Pleine Mer à Québec. Les vitesses de courants ont été obtenues à une profondeur de 5.5 mètres. Dû à la complexité des marées et des perturbations atmosphériques locales, les vitesses de courants et leurs directions réelles peuvent être considérablement différentes des données fournies. À d'autres endroits, les flèches cartographiées indiquent les directions et les approximatives du flot et du jusant. Dans tous les cas, les directions et les vitesses sont basées sur la marée moyenne

## TIDAL CURRENTS

Approximate directions and rates of the tidal currents at the lettered positions are given in the table and are referred to High Water at Québec. The current measurements were taken at a depth of 5.5 metres. Actual current speed and direction may vary considerably with those given due to the complexity of the tides and local atmospheric disturbances. At other locations, current arrows are used to indicate the approximate directions and rates at flood and ebb tide. In all cases, the directions and rates are for mean tides only.

## COURANTS DES MARÉES MOYENN
## TIDAL STREAMS, MEAN TIDES

Basé sur PM (Québec)
Referred to HW (Québec)

| Heure | A 47°02.1'N 70°46.0'W | | B 47°05.0 70°43.8 | |
|---|---|---|---|---|
| -5 | 197° | 0.8 Kn | 220° | 1.4 |
| -4 | 220° | 1.7 Kn | 214° | 3.0 |
| -3 | 229° | 1.9 Kn | 210° | 2.7 |
| -2 | 214° | 1.5 Kn | 218° | 2.5 |
| -1 | 218° | 0.7 Kn | 218° | 1.5 |
| PM | Perp./Turns | 0.3 Kn | Perp./Turns | 0.6 |
| +1 | 066° | 0.9 Kn | 040° | 1.9 |
| +2 | 057° | 1.6 Kn | 044° | 1.9 |
| +3 | 048° | 2.0 Kn | 030° | 2.0 |
| +4 | 050° | 1.6 Kn | 034° | 2.9 |
| +5 | 052° | 1.9 Kn | 038° | 3.0 |
| +6 | 050° | 1.6 Kn | 040° | 3.1 |

RIVIÈRE SAINTE - ANNE

Ruisseau de la Friponne

Bn Or

Cap Tourmente

Anse de la Montée du Lac

Racon

CAP BAULE

BANC DU

Cul-de-Sac du Cap Brûlé

BATTURES DE LA POINTE AUX PRÊTRES

Cap-Tourmente

Petite-Ferme

Le Petit Cap

Saint-Joachim

Pointe aux Prêtres

Rivière Marsolet

REFUGE D'OISEAUX BIRD SANCTUARY

Chy

Sp

Battures de la Traverse

Pointe Argentenay

BANC D'ORLÉANS

Anse aux Canards

Pointe chez East

Pointe aux Oignons

Moulin

Ruisseau du

Pointe Bellerive

Saint-François

Public

Pointe Bellevue

NORD

Bancs de l'Île Madame

Banc de Cent

Île au Ruau

Banc de l'Île au Ruau

Banc de la Grosse Île

Passage de la Patience

Île Patience

La Grosse Île

Îles Brothers

Passage de la Quarantaine

Île Gointon

Île Sainte-Marguerite

Île la Sottise

Batture Ile Sainte-Marguerite

Haut-fond de la Grosse Île

Rocher de la Grosse Île

Barre de la Grosse Île

Banc Empress

Rocher Wye

CHENAL DE

Île à Dau

Île à Deux Tas

Île à Cy

Ansa de la Montée du Lac

Ansa aux Canards

Ansa Verte

Ruisseau

Ru

Bn Or

Racon

Public

Sp

Chy

RM

RS

RCy

Cy S

SM

Bo

M

F 37m

F 20m

F 25m

Fl R

Fl G

Q G

Q R

Fl R 10s 10m 15M

Fl G 10s 10m 15M

2 Kts

1 Kts

4 Kts

2 Kts

2 Kts

024°

204°

213½°

035½°

254°

079°

K104

K102

K107

K116

K123

K131

K135

K139

K141

K143

K145

K147

K149

K151

K153

K155

K157

K159

K161

K163

K165

K167

K169

K171

K173

K175

K177

K179

K181

K183

K185

K187

K189

K191

K193

K195

K197

K199

K201

K203

K205

K207

K209

K211

K213

K215

K217

52' 51' 50' 49' 48' 47' 46' 45' 44' 43' 42' 41' 70° 40' 39' 38' 37'

EC

AWRENCE RIVER

# OCHON
# ÉBEC

0'N) Scale

tor

are in metres and are reduced to Chart (Lowest Normal Tide), which at u-Cochon is 2.6 metres, at hier-sur-Mer is 2.5 metres, at Saint-François etres and at Québec is 2.0 metres below detic Datum (GD).

ATIONS, spot elevations and clearances are s above Higher High Water, Large Tide. erlined figures on drying areas or in brackets drying features are in metres above r Datum. The contour interval is 30 metres.

ZONTAL DATUM: North American Datum 1983 ), which is equivalent to WGS 84.

S: Surveyed by the Canadian rographic Service, 1974-1976, 1982. phy is from National Topographic System .

Symbols and Abbreviations, see Chart No. 1.

SILTING

e continual silting, dredging is carried out odically to the depths shown but mariners tioned that varying amounts of refilling be expected.

RENSEIGNEMENTS SUR LES MARÉES / TIDAL INFORMATION

| LOCALITÉ / LOCATION | Altitude au-dessus du zéro des cartes / Elevation above Chart Datum | | | | |
|---|---|---|---|---|---|
| | Grande marée/Large Tide | | Marée moyenne/Mean Tide | | Niveau moyen de l'eau / Mean Water Level |
| | PMS/HHW | BMI/LLW | PMS/HHW | BMI/LLW | |
| | mètres/metres | mètres/metres | mètres/metres | mètres/metres | mètres/metres |
| Sault-au-Cochon | 6.2 | -0.1 | 5.3 | 0.5 | 2.8 |
| La Grosse Île | 6.5 | 0.1 | 5.4 | 0.4 | 2.8 |
| Berthier-sur-Mer | 6.3 | 0.2 | 5.1 | 0.5 | 2.6 |
| Saint-François | 6.5 | 0.0 | 5.2 | 0.7 | 2.9 |
| Québec(Lauzon) | 5.7 | -0.1 | 4.8 | 0.8 | 2.6 |

AIDES À LA NAVIGATION

Pour les renseignements complets sur les aides à la navigation, on doit consulter les cartes à plus grande échelle et le Livre des feux, des bouées et des signaux de brume.

AIDS TO NAVIGATION

For complete details of aids to navigation, the larger scale charts and List of Lights, Buoys and Fog Signals must be consulted.

SERVICES DE TRAFIC MARITIME

Point d'appel numéroté pour les Services de trafic maritime; la flèche indique la direction du mouvement du navire.
Pour plus de renseignements concernant ces services, consulter l'Avis aux navigateurs n° 25 de chaque année.

(11)

VESSEL TRAFFIC SERVICES

Traffic Services calling-in point with number; arrow indicates direction of vessel movement.
For additional information concerning these services, see Notice to Mariners No. 25 of each year.

CÂBLES

Les signes conventionnels des câbles sous-marins et aériens ne différencient pas les câbles conducteurs d'électricité, souvent à haute tension, des autres câbles de service. Les navigateurs prendront garde en passant sous tous les câbles aériens et éviteront de jeter l'ancre ou d'effectuer des opérations de fond à proximité des câbles sous-marins. La hauteur libre d'un câble aérien peut varier de sa valeur cartographiée à cause des changements dans les conditions atmosphériques, les niveaux d'eau et autres facteurs. Pour plus de renseignements, consulter l'Avis aux navigateurs n° 16 de chaque année et le volume approprié des Instructions nautiques du SHC.

CABLES

The symbols for submarine and overhead cables do not differentiate between cables conducting electric power, often at high voltages, and other types of utility cables. Mariners are advised to exercise caution when passing under all overhead cables and to avoid anchoring or conducting seabed operations in the vicinity of submarine cables. The clearance of an overhead cable may differ from its charted value due to changes in atmospheric conditions, water levels and other factors. For additional information, consult Notice to Mariners No. 16 of each year, and the appropriate volume of CHS Sailing Directions.

Sault-au-Cochon
Cap d'Éboulis Fl 6s 16m 8M
Anse aux Vaches
CHENAL DU NORD
REFUGE D'OISEAUX
BIRD SANCTUARY
Pointe d'Allaire
Anse aux Bardeaux
Pointe du Débarquement
Cap Gribane
La Grande Anse
Cap Rouge
Voir/See note
ENSABLEMENT/SILTING
Anse aux Canelliers
Cap Brûlé
Iso 2s 40m 5M
Anse de la Montée du Lac
Cap Tourmente
Racon
SAINTE-ANNE
BRISANTS DU CAP BRÛLÉ
Caye à Nauby
La Baleine
Caye du Père-Édouard
Caye du Rocher de Chasse
Rocher de Chasse
Caye de la Prairie
Caye du Cap Brûlé
Banc des Ilets
Rocher à Bon Or
Bn Or
Récifs de Longue Pointe
213°
221°
041°
033°
103°
600s
630s
680s
530s
450s
500s
470s
RLts

52' 51' 50' 49' 48' 47' 46' 45' 44' 43' 42' 41' 70° 40' 39' 38' 37' 36'

RENCE RIVER

# CHON
# BEC

Scale

metres and are reduced to Chart west Normal Tide), which at on is 2.6 metres, at r-Mer is 2.5 metres, at Saint-François nd at Québec is 2.0 metres below tum (GD).

spot elevations and clearances are ve Higher High Water, Large Tide. figures on drying areas or in brackets features are in metres above the contour interval is 30 metres.

DATUM: North American Datum 1983 ch is equivalent to WGS 84.

surveyed by the Canadian Service, 1974-1976, 1982 from National Topographic System

ls and Abbreviations, see Chart No. 1.

SILTING

nual silting, dredging is carried out to the depths shown but mariners that varying amounts of refilling ected.

RENSEIGNEMENTS SUR LES MARÉES / TIDAL INFORMATION

| LOCALITÉ LOCATION | Altitude au-dessus du zéro des cartes / Elevation above Chart Datum | | | | |
|---|---|---|---|---|---|
| | Grande marée/Large Tide | | Marée moyenne/Mean Tide | | Niveau moyen de l'eau Mean Water Level |
| | PMS/HHW | BMI/LLW | PMS/HHW | BMI/LLW | |
| | mètres/metres | mètres/metres | mètres/metres | mètres/metres | mètres/metres |
| Sault-au-Cochon | 6.2 | -0.1 | 5.3 | 0.5 | 2.8 |
| La Grosse Île | 6.5 | 0.1 | 5.4 | 0.4 | 2.8 |
| Berthier-sur-Mer | 6.3 | 0.2 | 5.1 | 0.5 | 2.6 |
| Saint-François | 6.5 | 0.0 | 5.2 | 0.7 | 2.9 |
| Québec(Lauzon) | 5.7 | -0.1 | 4.8 | 0.8 | 2.6 |

## AIDES À LA NAVIGATION

Pour les renseignements complets sur les aides à la navigation, on doit consulter les cartes à plus grande échelle et le Livre des feux, des bouées et des signaux de brume.

## AIDS TO NAVIGATION

For complete details of aids to navigation, the larger scale charts and List of Lights, Buoys and Fog Signals must be consulted.

## SERVICES DE TRAFIC MARITIME

Point d'appel numéroté pour les Services de trafic maritime; la flèche indique la direction du mouvement du navire.
Pour plus de renseignements concernant ces services, consulter l'Avis aux navigateurs n° 25 de chaque année.

## VESSEL TRAFFIC SERVICES

Traffic Services calling-in point with number; arrow indicates direction of vessel movement.
For additional information concerning these services, see Notice to Mariners No. 25 of each year.

## CÂBLES

Les signes conventionnels des câbles sous-marins et aériens ne différencient pas les câbles conducteurs d'électricité, souvent à haute tension, des autres câbles de service. Les navigateurs prendront garde en passant sous tous les câbles aériens et éviteront de jeter l'ancre ou d'effectuer des opérations de fond à proximité des câbles sous-marins. La hauteur libre d'un câble aérien peut varier de sa valeur cartographiée à cause des changements dans les conditions atmosphériques, les niveaux d'eau et autres facteurs. Pour plus de renseignements, consulter l'Avis aux navigateurs n° 16 de chaque année et le volume approprié des Instructions nautiques du SHC.

## CABLES

The symbols for submarine and overhead cables do not differentiate between cables conducting electric power, often at high voltages, and other types of utility cables. Mariners are advised to exercise caution when passing under all overhead cables and to avoid anchoring or conducting seabed operations in the vicinity of submarine cables. The clearance of an overhead cable may differ from its charted value due to changes in atmospheric conditions, water levels and other factors. For additional information, consult Notice to Mariners No. 16 of each year, and the appropriate volume of CHS Sailing Directions.

CHENAL DU NORD

Sault-au-Cochon

Cap d'Éboulis

Anse aux Vaches

REFUGE D'OISEAUX
BIRD SANCTUARY

Pointe d'Allian

Anse aux Bardeaux

Pointe du Débarquement

Cap Tribord

Cap Rouge

Voir/See note
ENSABLEMENT/SILTING

Anse aux Canelliers

Cap Brûlé

Cap Tourmente

SAINTE - ANNE

ÎLES DU CAP BROYÉ

Caye du Père-Édouard

Caye à Rouby

La Baleine

Caye de Roche de Chasse

Caye de la Prairie

Caye du Cap Brûlé

Banc des Îlets

Chenal de Repentigny

213½°

041°

033½°

RIVIÈRE SAINTE

Rivière Jean - Larose

Ruisseau de la Friponne

Cap Tourmente

Bn Or

BANC DU CAP

Racon

Cul-de-Sac du Cap brûlé

BATTURES DE LA POINTE AUX PRÊTRES

Cap-Tourmente

Petite-Ferme

Le Petit Cap

Saint-Joachim

Pointe aux Prêtres

Rivière Marsolet

REFUGE D'OISEAUX
BIRD SANCTUARY

Beaupré

Chy

FER

L'ÎLE D'ORLÉANS

BANC D'ORLÉANS

Pointe Argentenay

Anse aux Canards

Pointe chez East

Pointe aux Oignons

Moulin

Ruisseau du

Le Petit Cap

Pointe Bellerive

Saint-François

Anse Volfe

Pointe Bellevue

Pointe à Dannead

Pointe Dauphine

Battures de la Traverse

Banc du Centre

Ruau

Ile au

Bancs de l'Ile Madame

Ile Madame

Ile Gointon

Ile Patience

Iles Brothers

La Grosse Ile

Passage de la Quarantaine

Passe de la Grosse Ile

Ile la Sottise

Balture Sainte-Marguerite

Haut-fond de la Grosse Ile

Rocher de la Grosse Ile

Public Dock

Banc Empress

Rocher Cassault

Voir note ENSABLEMENT/See note SILTING

213½°

226°

046°½

254°

074°

053½°

018° W 1999 (2°E)

2 Ka

1 Ka

ÎLE D'ORLÉANS

CHENAL DU NORD

CHENAL DU SUD

TRAVERSE DU CHENAL

Pointe à Danneau

Pointe Dauphine

Bn Or

Île Madame

Anse à Laverdière

Pointe à Blaye

Pointe Saint-Jean

Saint-Jean

Rivière Lafleur

Rivière-Lafleur

Pointe Saint-Michel

Pointe Samson

Pointe à Labrecque

Banc de Saint-Vallier

REFUGE D'OISEAUX
BIRD SANCTUARY
Anse de Saint-Vallier

Saint-Vallier

Saint-Michel

Pointe De La Durantaye

Rivière Boyer

Rivière des Mères

Pointe de Saint-Vallier

Anse de Bellechasse

Ruisseau Bellechasse

Pointe Verte

Trou de Berthier

Pointe de Berthier Est

Anse de Berthier

Île de Bellechasse

Berthier-sur-Mer

Pointe Rouge

Ruisseau Corriveau

ROUTE TRANSCANADIENNE / TRANS-CANADA HWY

Saint-François-de-Montmagny

Les Caps

Fl R 6s 10m 12M Racon

Fl G K123

Fl G K127

Fl R K131

Fl G K131

Fl G H131

Fl R K140

Fl G K141

Q(6)+LFl 15s

Fl Y 6s 13m 6M

Bwk

F 36m

F 63m

70°56'45.30"W

COURANTS DE MARÉE

Les directions et les vitesses approximatives de courants de marée, aux positions marquées avec des lettres, sont fournies dans le tableau et sont basées sur la Pleine Mer à Québec. Les vitesses de courants ont été obtenues à une profondeur de 5.5 mètres. Dû à la complexité des marées et des perturbations atmosphériques locales, les vitesses de courants et leurs directions réelles peuvent être considérablement différentes des données fournies. À d'autres endroits, les flèches cartographiées indiquent les directions et les approximatives du flot et du jusant. Dans tous les cas, les directions et les vitesses sont basées sur la marée moyenne seulement.

TIDAL CURRENTS

Approximate directions and rates of the tidal currents at the lettered positions are given in the table and are referred to High Water at Québec. The current measurements were taken at a depth of 5.5 metres. Actual current speed and direction may vary considerably with those given due to the complexity of the tides and local atmospheric disturbances. At other locations, current arrows are used to indicate the approximate directions and rates at flood and ebb tide. In all cases, the directions and rates are for mean tides only.

COURANTS DES MARÉ
TIDAL STREAMS, M

| Heures | A 47°02.1'N 70°46.0'W | | B |
|---|---|---|---|
| | Basé sur PM (Qué | | |
| | Referred to HW (Qu | | |
| -5 | 197° | 0.6 Kn | 22 |
| -4 | 220° | 1.7 Kn | 21 |
| -3 | 229° | 1.9 Kn | 21 |
| -2 | 214° | 1.5 Kn | 21 |
| -1 | 216° | 0.7 Kn | 21 |
| PM | Renv / Turns | 0.3 Kn | Re |
| +1 | 068° | 0.9 Kn | 04 |
| +2 | 057° | 1.6 Kn | 04 |
| +3 | 048° | 2.0 Kn | 03 |
| +4 | 050° | 1.8 Kn | 03 |
| +5 | 052° | 1.8 Kn | 03 |
| +6 | 050° | 1.6 Kn | 04 |

56' 70° 55' 54' 53' 52' 51' 50' 49' 48' 47' 46' 45' 44' 43' 42' 41' 70

TROIS-RIVIÈRES

TROIS-RIVIÈRES-OUEST

Cartouche Inlet

Cartouche Point des Ormes

DEBUT

Sainte-Catherine

Voir/See note VERGLAS/ICE

Voir/See note COURANT/CURRENT

Pointe-des-Ormes

Pointe aux Ormes

Pont Laviolette

Rivière Godefroy

Rivière Marguerite

Baie-Jolie

Tle aux Sternes

Pointe-du-Lac

Pointe du Lac

Haut-fond de la Pointe

Pointe Saint-Quentin

Port-Saint-François

Pointe aux Sables

Saint-Grégoire

Pointe du Lac 236°

Voir/See NOTE BOUÉES/BUOYS

Pointe du Hamsau

La-Pointe-du-Hamsau

PIERRE

AVERTISSEMENT / WARNING

Limites des zones de pratiques de tir et d'exercices. Consulter l'Avis aux navigateurs n° 35 de chaque année.

CYR 606

Limits of Firing Practice and Exercice Areas. See Notice to Mariners No. 35 of each year.

Milles marins (46°15'N) Nautical Miles

Petite rivière Yamachiche

Rivière Yamachiche

Yamachiche

Bn Or

Ansa de Yamachiche

Pointe de Yamachiche

Aneres
Anchors

Les Plaines

Pointe-du-Lac

Pointe du Lac

Haut-fond de la Pointe du Lac

Traverse Nicolet

Courbe Pointe-du-Lac

Courbe Nicolet

Voir/See note M
PROFONDEUR DU CHENAL
CHANNEL DEPTH

Voir/See note
AIDES À LA NAVIGATION
AIDS TO NAVIGATION

Course Pointe du Lac

Iso R 2s 13m 5 M

Iso G 10m
FI G 6s

Recon

Bn Or

Île aux Sternes

Voir/See note
PROFONDEUR DU CHENAL
CHANNEL DEPTH

Battures à Baron

Battures au Fer

Banc des Anglais

Baie Wolfe

Voir/See note
BOUÉES/BUOYS

DIAGRAMME/DIAGRAM
Voir instructions nautiques
See Sailing Directions

Île Moras

Île du Domaine

Île Lozeau

Île Hautlass

Nicolet

Pointe du Petit Chenal

Île Bougainville

Baie du Febvre

SANCTUAIRE D'OISEAUX
BIRD SANCTUARY

Pointe aux Pois

Rivière Nicolet

Pointe du Hameau

Pointe Saint-Antoine

Pointe Saint-Gérard

Pointe Lataille

Pointe Saint-Jean

Pointe Saint-Sulpice

Pointe Saint-Pierre

Pointe Saint-Paul

Pointe Saint-Jacques

Pointe Saint-Joseph

Pointe Saint-Ignace

Pointe Saint-Thomas

Yamachiche
Petite rivière Yamachiche
Rivière Yamachiche
Anse de Yamachiche
Pointe de Yamachiche
Bn Or
Ancres
Anchors
056°
070°
250°
Courbe Yamachiche
Courbe de Pointe du Lac
11.0m
10.7
Racon
FIR
FIG
FG 9m
Voir/See note M
PROFONDEUR DU CHENAL
CHANNEL DEPTH
Voir/See note
AIDES À LA NAVIGATION
AIDS TO NAVIGATION
FG 49m
Pointe du Lac
Haut-fond de la pointe du Lac
FG 12m
Iso Y 2s 12m
Courbe Pointe-du-Lac
1N km
096½°
Traverse Nicolet
276½°
11.0m
Batteries à Bizon
Basse dérivé Privately Buoyed
Bk N
Basse Wilkie
Basse dérivé
Privately Buoyed
Bk N
236°
Tie Moras
Tie du Domaine
Pointe du Petit Chenal
Tie Bougainville
Baie du Febvre
SANCTUAIRE D'OISEAUX
BIRD SANCTUARY
Pointe aux Pois
Pointe à Garenne
Pointe aux Raisins
016½°W 1996 (TE)
CYR 606
Dir 140°

TROIS-RIVIÈRES

TROIS-RIVIÈRES-OUEST

Pointe-du-Lac

Sainte-Catherine

Pointe-des-Ormes

Baie-Jolie

Tie aux Sternes

Saint-François

Pont Laviolette

Rivière Godefroy

Rivière Marguerite

Cartouche Inset

Course Pointe des Ormes

Course Pointe du Lac

Haut-fond de la Pointe du Lac

Battures aux Outardes

Battures à Biron

Battures Lafrenaie

Pointe Saint-François

Banc des Anglais

Pointe Sable

Voir/See note VERGLAS/ICE

Voir/See note COURANT/CURRENT

Voir/See note BOUÉES/BUOYS

016½° W 1997 (°E)

276½° traverse Wyeth

096½°

049°

058°

229°

037½°

AIDES D'ÉTÉ PROPOSÉES PAR AASL

ESPARS ACTUELS

ESPARS PROPOSÉS PAR AASL

AVERTISSEMENT / WARNING

Limites des zones de pratiques de tir et d'exercices. Consulter l'Avis aux navigateurs n° 35 de chaque année.

CYR 606

Limits of Firing Practice and Exercice Areas. See Notice to Mariners No. 35 of each year.

Milles marins (ARQHEM) Nautical Miles

# Appendix D: Conventional LOS Results

# Buoyage Review

***Saguenay Approaches***
***Traverse du Nord***
***Port of Trois Rivières to Yamachiche Anchorage Area***
**(May 1999)**

## Purpose

The buoyage at the above three sites has been reassessed to determine the relevance of the summer aids to navigation in place. We based the assessment on the basic principles outlined in the Level of Service Review directives. It should be noted that the review looked at the needs of Category 1 users, i.e. certified commercial users. This made it easier to draw a parallel between this review and the risk analysis project currently under way.

We did not review the winter buoyage system because we were already aware that it posed a problem for us by not meeting current standards. Further details are provided in the Results section.

## Methodology

An assessment sheet was drawn up to make it easier to list the reasons why the aids to navigation are in place (or will be installed). The assessment sheet was based specifically on the following assumptions, principles and guidelines, issued by Ottawa in recent years, that apply to this buoyage review (and were still in effect when the review was conducted):

1. If there is no range light ahead of the vessel, two buoys are required on the starboard side. (Two buoys are required on the starboard side when a vessel moves through a narrow channel and has no range light ahead of it.);
2. If there is a range light ahead of the vessel, one buoy is required on the starboard side. (One buoy is required on the starboard side when a vessel moves through a narrow channel and has a range light ahead of it.);
3. Marker at apex of turn;
4. Markers at beginning and end of turn;
5. Turn recovery marker;
6. Channel entrance markers;
7. Compliance with buoy spacing requirements in a restricted channel (i.e. spacing between two buoys should be equal to four to five times the width of the channel);
8. Radar target based on radar scale selected when the vessel transits in less than design visibility conditions (we are required to provide radar targets if we are certain that users are transiting in less than design visibility conditions).

## Ranges

We have stressed the importance of ensuring that range lights and day markers have adequate sensitivity and day range. These elements have not always been taken into consideration in past years.

## Luminous Range

The luminous and visual ranges of the aids to navigation were checked in an earlier preliminary study. No malfunctions (defective ranges) were reported. Except for the ranges of the range lights, our review does not examine the luminous range aspect.

## Dead Reckoning (DR) vs Direct Observation Pilotage Navigation

Instead of the dead reckoning method, pilots are using direct observation pilotage and/or electronic navigation methods (radar, Loran C, electronic maps/DGPS). Dead reckoning navigation is now generally considered an obsolete method for commercial class users owing to the tools that are now available to determine ship positions. We therefore did not take this method into consideration in the various study areas.

## Theoretical Availability and Design Visibility

We define theoretical availability to be the minimum percentage of time (in the worst month of the navigation season, i.e. when visibility is lowest) during which ship operators (depending on local weather conditions) can use (i.e. see or hear) a properly functioning aids to navigation system.

The aids to navigation availability percentage has been set at 75 percent. This availability corresponds to a meteorological visibility percentage that can be determined locally by consulting Environment Canada data. To help explain the process, we have included a sample of data (see attached) used to determine the design visibility (based on theoretical availability of 75 percent) of the east section of Lake St. Pierre.

These data were analysed to arrive at a summer visibility criterion for the purposes of the review of 2.2 nmi for the Saguenay approaches and 5.0 nmi for the Traverse du Nord and the eastern section of Lake St. Pierre.

## Volume of traffic

- ***Saguenay River approaches:*** Each year, between 200 and 215 commercial vessels are guided by pilots through the Saguenay River approaches. During the summer

period, a very large number of tour boats and pleasure craft increase the volume of traffic in this corridor.

- ***Traverse du Nord:*** Each year, more than 5,500 commercial ship transits are reported in this sector.

- ***Yamachiche:*** Each year, more than 4,500 commercial ship transits are reported in this sector.

## Ship Draught

The following maximum draughts have been reported in recent years:

- ***Saguenay River approaches:*** 13.4 m for 52,000-tonne vessels;
- ***Traverse du Nord:*** 16.0 m for 153,000-tonne vessels;
- ***Yamachiche:*** 11.6 m for 57,000-tonne vessels.

## Results

- ***By consulting the current directives and standards and the procedures manual*** used to design short-range aids to navigation, it was easy to identify the rationale for all of the aids to navigation (floating and fixed) currently provided in the three study areas. A very large portion of the floating aids identified shoal and/or dredged channel areas, while a very large number of the fixed aids to navigation were ranges used to guide commercial vessels in their lateral movements. The few shore lights in the study areas provided visual or radar marks to help ships better position themselves in turns or near shoals (located close to dredged or undredged sections of the shipping channel).

- ***Design Visibility and Buoy Spacing*** – As explained above, a specific design visibility criterion was used for each study area. It was five nautical miles for the Traverse du Nord and Trois Rivières–Yamachiche sections and two nautical miles for the Saguenay approaches.

- ***Winter Buoyage Problem*** – We cannot conclude from the current design standards that the floating buoy system in the three study areas is adequate. In winter ice conditions, mariners cannot use the unlighted spar buoys (either with radar or visually, day or night) on a continuous basis.

  This conclusion holds true despite the fact that there are fewer ship transits, passings and crossings (commercial class only) in the winter period.

The installation of additional spar buoys, although helpful, cannot ensure that the desired level of service will be reached. We believe the option of additional fixed aids to navigation (e.g. near the K-107 buoy in the Traverse du Nord) could improve the quality of ship positioning. However, these additional aids to navigation would entail a very costly capital investment (over $1 million). The introduction of the DGPS and electronic maps may initiate a trend in the use of such methods (fixed aids) to improve ship positioning quality.

It is not our task here to decide whether having two pilots on board each Class 1 ship in the winter is enough to reduce the additional risk arising from the decreased use of floating aids to navigation in this season. We can assume, of course, that radar and pilotage marks would be used more frequently in winter. However, we cannot maintain that the increased use of electronic aids to navigation (on board ships) will ensure that transits in these navigable waters will take place in complete safety. We should ask ourselves whether we should rely entirely on the rather positive profile presented in the maritime incident statistics to maintain that we are providing an adequate winter aids to navigation system (although it does not meet the national design standards) to ensure the safe passage of ships.

- ***Range Problem*** – We noted that the day visual ranges of the range lights were often inadequate, at least from a theoretical standpoint. According to the day luminous range tables in use, the ranges of the lights do not adequately cover the length of the channel segment served by each range. In addition, the range of day markers installed on the ranges is inadequate at 40 percent of the sites. It would be costly and technically difficult to increase the day range of the lights and day markers.

  We also noted that the vertical and/or horizontal sensitivity of some ranges did not fully meet the current standards and prevented mariners from making maximum use of them. Given that the changes required to improve the performance of these ranges would be costly in most cases, we made certain there were enough existing buoys in the ranges to serve the sectors. This makes them all the more vital.

- ***Rationale for Aids to Navigation*** – The attached sample data contains a list of aids to navigation used in the three study areas along with the rationale for each one.

Daniel Crépault
May 17, 1999

| Name of Aid to Navigation | RANGE PROBLEMS | | | | TURNS | | | TURN RECOVERY | | OTHER | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C-48 | | | | | | | | | | X | X | | X | IDENTIFIES BOUNDARY OF 11-M DREDGED CHANNEL AND START OF 10.7-M CHANNEL. |
| C-49 | | | | X | | | | X | | X | | X | X | |
| C-52 | | | | | | | | | | X | X | | X | IDENTIFIES BOUNDARY OF 10.7-M DREDGED SECTION. |
| C-53 | | | | | X | | | | | X | | | X | |
| CAP MADELEINE DOWNBOUND RANGE | | | | | | | | | | | | | | SENSITIVITY OK; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 0% OF COURSE; DAY MARK RANGE OK. |
| C-61 | | | | | | | | | | X | X | | X | |
| C-63 | | | | | | | | X | | X | X | | X | |
| C-65 | | | | | | | | X | | | | | X | CHANGE OF PILOT AREA; BACK CURRENTS; REDUCED VESSEL SPEED. |
| ST ANGÈLE RANGE | | | | | | | | | | | | | | SENSITIVITY OK; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 40% OF COURSE; DAY MARK RANGE OK. |
| PONT LAVIOLETTE SL + RACON | | | | | | | | | | | | | | TO IDENTIFY PILLARS |
| C-67 | | | | | | | | | | | | | X | BACK CURRENT; CHANGE OF PILOT AREA; REDUCED VESSEL SPEED; AIDS VESSEL TRANSIT UNDER BRIDGE. |
| C-70 | | | | | | | | | | | X | | X | IDENTIFIES ANCHORAGE AREA |
| C-71 | | | | | | | | | | | X | | X | IDENTIFIES ANCHORAGE AREA |
| C-72 | | | | | | | | | | | X | | X | IDENTIFIES ANCHORAGE AREA |
| C-77 | | | X | | | | | | | | X | | X | |
| PORT ST FRANÇOIS RANGE | X | | | | | | | | | | | | | INSUFFICIENT SENSITIVITY; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 0% OF COURSE; DAY MARK RANGE OK. |
| PORT ST FRANÇOIS WL | | | | | | | | | | | X | | X | AIDS WITH VISUAL AND RADAR (RADAR REFLECTOR) IDENTIFICATION OF NEARBY SHOALS |
| S-2 | | | | | | | | X | | X | | | X | |
| S-3 | | | | | X | | | | | X | | | X | |
| S-4 | | | X | | X | | | | | X | X | | X | |
| S-6 | | | X | | X | | | | | X | X | | X | |
| NICOLET SL + RACON | | | | | | | | | | | | | X | |
| NICOLET RANGE | ± | | | | | | | | | | | | | SATISFACTORY SENSITIVITY; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 0% OF COURSE; DAY MARK RANGE OK. |
| S-8 | | | X | | X | | | | | | X | | X | |
| S-10 | | | X | | | X | | | | | X | | X | |
| S-12 | | | X | | | | | X | | X | X | X | X | |
| S-13 | | | | X | X | | | | | | X | | X | |

| Name of Aid to Navigation | RANGE PROBLEMS | | | | TURNS | | | TURN RECOVERY | OTHER | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-16 | | | X | | | X | | | | X | | X | |
| S-17 | | | | X | X | | | | | X | | X | |
| S-21 | | | X | | X | | | | | X | | X | |
| S-22 | | | | | X | | | X | | X | | X | |
| S-25 | | | X | | X | | | | | X | | X | |
| S-26 | X(J) | | | X | | | X | | | | | X | |
| S-27 | | | | X | | X | | | | | | X | |
| POINTE DU LAC RANGE | | | | | | | | | | | | X | SENSITIVITY OK; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 0% OF COURSE; DAY MARK RANGE OVER 1/2 OF CHANNEL + RADAR TARGET ON FR; Range matched with Yamachiche range. |
| S-31 | | | | X | | | | | X | X | X | X | |
| S-32 | X(J) | | | X | | | | X | X | | X | X | |
| S-43 | X(J) | | | X | | | | | X | X | X | X | |
| S-44 | | | | X | | | | | X | X | X | X | |
| S-51 | X(J) | | | X | | | | | X | X | X | X | |
| S-54 | | | | X | | | | | X | X | X | X | |
| S-58 | | | X | | | | | | X | X | X | X | |
| YAMACHICHE SL | | | | | | | | | | | | X | |
| YAMACHICHE RANGE | | | | | | | | | | | | X | SENSITIVITY OK; NIGHT RANGE OF LIGHT OK; DAY RANGE OF LIGHT 0% OF COURSE; DAY MARK RANGE OVER 1/2 OF CHANNEL; Range matched with Pointe du Lac range. |
| YAM B | | | | | | | | | | X | X | X | IDENTIFIES ANCHORAGE AREA |

| Name of Aid to Navigation | RANGE PROBLEMS | | | | TURNS | | | TURN RECOVERY | | OTHER | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K-91 | | | X | | | | | X | | X | X | X | X | |
| K-92 | N/D | | X | | | | | X | | X | | X | X | |
| K-95 | | | X | | | | | X | | X | | X | X | |
| K-96 | D | | X(D) | X(N) | | | | | | X | X | X | X | |
| K-99 | | | X | | X | | | X | | X | X | X | X | |
| K-100 | J | | X(D) | X(N) | X | | | X | | X | | X | X | |
| K-101 | | | | X | X | | | | | X | | X | X | |
| K-103 | | | | X | | | | X | | X | | X | X | |
| K-104 | | | X | | | | | X | | X | X | X | X | |
| K-107 | J | X | X(D) | X(N) | X | | | | | X | X | X | X | |
| K-108 | | X | X | | X | | | | | X | X | X | X | |
| K-111 | | | | X | | | | | | X | | X | X | |
| K-112 | D/N | | X | | | | | X | | X | X | X | X | |
| K-115 | | | | X | | | | | | X | X | X | X | |
| K-116 | D | | X(D) | X(N) | | | | | | X | X | X | X | |
| K-119 | D | X | X(D) | X(N) | | | | | | X | X | X | X | |
| K-120 | D | | X(D) | X(N) | | | | | | X | | X | X | |
| ST FRANÇOIS WL | | | | | | | | | | | | | X | |
| K-123 | D | X | X(D) | X(N) | | | | | | X | X | X | X | |
| K-124 | D | | X() | X(N) | | | | | | X | X | X | X | |
| K-127 | D | X | X(D) | X(N) | | | | | | X | X | X | X | |

| Name of Aid to Navigation | RANGE PROBLEMS | | | | TURNS | | | TURN RECOVERY | | OTHER | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | | X(D) | X(N) | | | | | | X | X | X | X | |
| K-128 | D/N | X | X | | | | | | | X | X | X | X | |
| K-131 | | | | X | | | | | | X | X | X | X | |
| K-132 | | | | | | | | X | | X | | X | X | |
| K-135 | | | | X | | | | X | | X | | X | X | |
| K-136 | | | | | | | | | | | | | X | |
| ST JEAN WL + RACON | | X | | | | | | | | | | | | LATERAL PERCEPTIBILITY DOES NOT MEET STANDARDS AT CHANNEL END; DAY MARK RANGE 1/4 OF COURSE; NIGHT RANGE OF LIGHT 90% OF COURSE; DAY RANGE OF LIGHT 0% OF COURSE; Range matched with St Michel Range. |
| BANC BRÛLÉ RANGE UPBOUND | | X | | | | | | | | | | | | LATERAL PERCEPTIBILITY DOES NOT MEET STANDARDS AT CHANNEL END; DAY MARK RANGE 3/4 OF COURSE; NIGHT RANGE OF LIGHT 100% OF COURSE; DAY RANGE OF LIGHT 0% OF COURSE. |
| CAP GRIBANE RANGE | | | | | | X | | | | | | | | SENSITIVITY OK; DAY MARK RANGE 0% OF COURSE; NIGHT RANGE OF LIGHT 85% OF COURSE; DAY RANGE OF LIGHT 0% OF COURSE. |
| ARGENTENAYE RANGE | | | | | | | | | | | | | | |
| CAP BRÛLÉ SL | | | | | X | | | | | | | | | SENSITIVITY OK; DAY MARK RANGE 0% OF COURSE; NIGHT RANGE OF LIGHT 80% OF COURSE; DAY RANGE OF LIGHT 0% OF COURSE. Range matched with Banc Brûlé downbound range. |
| ST MICHEL RANGE | | | | | | | | | | | | | | |

# Appendix E: Aids to Navigation Configurations

| | | | | Position (in NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| Cap Rouge FR | 1895.6 | 8C | range light | 47°07'30.038" | 070°42'06.041" |
| Cap Rouge RR | 1895.7 | 8C | range light | 47°07'05.055" | 070°42'38.078" |
| *Neptune* Beacon | 6893.2 | 10A | beacon | 47°09'42.422" | 070°36'27.666" |
| K-092 | 1893.6 | 12A | 2.9-m bell buoy | 47°09'35.437" | 070°39'40.530" |
| K-091 | 1893.5 | 12A | 2.9-m bell buoy | 47°09'16.179" | 070°39'36.524" |
| *Pointe Alliance* Beacon | 6893.3 | 10A | beacon | 47°10'08.827" | 070°39'50.998" |
| Pointe Argentenay FR | 1910.5 | 8B | range light | 47°00'27.870" | 070°48'18.450" |
| Pointe Argentenay RR | 1910.6 | 8C | range light | 46°59'13.116" | 070°49'30.762" |
| *12-Foot Rock* Beacon | 6895.75 | 10A | beacon | 47°06'16.225" | 070°40'19.899" |
| K-096 | 1894 | 12A | 2.9-m bell buoy | 47°08'39.284" | 070°40'29.906" |
| K-096 | Idem | 15A | 1.0-m spar buoy | 47°08'39.284" | 070°40'29.906" |
| K-095 | 1895 | 12A | 2.9-m bell buoy | 47°08'04.806" | 070°40'46.146" |
| K-099 | 1895.8 | 12A | 2.9-m bell buoy | 47°06'53.421" | 070°41'55.698" |
| K-100 | 1895.9 | 12A | 2.9-m bell buoy | 47°06'38.929" | 070°42'27.186" |
| Cap Gribane FR | 1895.2 | 8C | range light | 47°08'27.244" | 070°41'08.788" |
| Cap Gribane RR | 1895.3 | 8C | range light | 47°08'40.433" | 070°41'00.237" |
| *Cap Tourmente* Beacon | 6903.2 | 10A | beacon | 47°05'16.994" | 070°44'35.038" |
| K-101 | 1895.91 | 12A | 2.9-m bell buoy | 47°06'15.852" | 070°42'26.307" |
| K-104 | 1897 | 12A | 2.9-m bell buoy | 47°05'14.933" | 070°43'21.537" |
| K-103 | 1896 | 12A | 2.9-m bell buoy | 47°05'10.941" | 070°43'08.309" |
| Banc Brûlé Racon | "1900" | 7A | racon | 47°05'22.548" | 070°42'38.850" |
| *Friponne* Beacon | 6905.3 | 10A | beacon | 47°04'18.907" | 070°47'06.945" |
| K-107 | 1904 | 12A | 2.9-m bell buoy | 47°03'46.184" | 070°44'03.106" |
| K-108 | 1905 | 12A | 2.9-m bell buoy | 47°03'50.929" | 070°44'15.841" |
| K-108 | Idem | 15A | 1.0-m spar buoy | 47°03'50.929" | 070°44'15.841" |
| FR Upstream from Cap Brûlé | 1900 | 8C | range light | 47°05'22.548" | 070°42'38.850" |
| RR Upstream from Cap Brûlé | 1901 | 8C | range light | 47°05'49.976" | 070°42'12.384" |
| *Décor* Beacon | 6910.3 | 10A | beacon | 47°01'20.016" | 070°47'46.611" |
| K-111 | 1906 | 12A | 2.9-m bell buoy | 47°02'31.844" | 070°45'14.737" |
| K-112 | 1908 | 12A | 2.9-m bell buoy | 47°02'37.275" | 070°45'26.806" |
| K-112 | Idem | 15A | 1.0-m spar buoy | 47°02'37.275" | 070°45'26.806" |
| K-115 | 1909 | 12A | 2.9-m bell buoy | 47°01'18.207" | 070°46'25.625" |
| K-116 | 1910 | 12A | 2.9-m bell buoy | 47°01'23.636" | 070°46'37.692" |
| K-116 | Idem | 15A | 1.0-m spar buoy | 47°01'23.636" | 070°46'37.692" |
| *East Ile Madame* Beacon | 6912.3 | 10A | beacon | 46°58'45.677" | 070°46'58.373" |
| *West Ile Madame* Beacon | 6913.6 | 10A | beacon | 46°57'41.188" | 070°48'10.385" |
| K-119 | 1911 | 12A | 2.9-m bell buoy | 47°00'04.557" | 070°47'36.459" |
| K-120 | 1912 | 12A | 2.9-m bell buoy | 47°00'09.984" | 070°47'48.523" |
| K-120 | 1912 | 15A | 1.0-m spar buoy | 47°00'09.984" | 070°47'48.523" |
| St François WL | 1913 | 4C | wharf light | 46°59'47.578" | 070°48'29.496" |
| *Carré* Beacon | 6913.5 | 10A | beacon | 46°58'38.457" | 070°49'44.804" |
| St Michel FR | 1918 | 8C | range light | 46°52'31.008" | 070°54'59.790" |
| St Michel RR | 1919 | 8C | range light | 46°51'43.930" | 070°55'44.758" |
| K-123 | 1913.4 | 13A | 1.8-m NT | 46°58'50.900" | 070°48'47.234" |
| K-124 | 1912.5 | 13A | 1.8-m NT | 46°58'56.324" | 070°48'59.296" |
| K-127 | 1914 | 12A | 1.8-m *moine* | 46°57'37.231" | 070°49'57.955" |
| K-128 | 1915 | 12A | 2.9-m bell buoy | 46°57'42.654" | 070°50'10.013" |
| K-128 | Idem | 15A | 1.0-m spar buoy | 46°57'42.654" | 070°50'10.013" |
| *Gabriel* Beacon | 6917.7 | 10A | beacon | 46°56'15.755" | 070°52'21.254" |
| K-131 | 1916 | 12A | 2.9-m bell buoy | 46°56'41.704" | 070°50'51.217" |
| K-132 | 1917 | 12A | 2.9-m bell buoy | 46°56'45.475" | 070°51'04.856" |
| K-132 | Idem | 15A | 1.0-m spar buoy | 46°56'45.475" | 070°51'04.856" |
| K-135 | 1917.3 | 12A | 2.9-m bell buoy | 46°55'53.597" | 070°51'37.331" |
| DAME | 1922 | 12A | 2.9 m | 46°55'53.078" | 070°50'30.283" |
| K-136 | 1917.2 | 12A | 2.9-m bell buoy | 46°55'31.784" | 070°52'15.477" |
| K-136 | Idem | 15A | 1.0-m spar buoy | 46°55'31.784" | 070°52'15.477" |
| St Jean WL | 1923 | 4C | wharf light | 46°54'56.524" | 070°53'46.961" |
| St Jean Racon | "1923" | 7A | racon | 46°54'56.524" | 070°53'46.961" |

| | | | | Position (In NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| Cap Rouge FR | 1895.6 | 8C | range light | 47°07'30.038" | 070°42'06.041" |
| Cap Rouge RR | 1895.7 | 8C | range light | 47°07'05.055" | 070°42'38.078" |
| *Neptune* Beacon | 6893.2 | 10A | beacon | 47°09'42.422" | 070°36'27.666" |
| K-092 | 1893.6 | 12A | 2.9-m bell buoy | 47°09'35.437" | 070°39'40.530" |
| K-091 | 1893.5 | 12A | 2.9-m bell buoy | 47°09'16.179" | 070°39'36.524" |
| *Pointe d'Alliance* Beacon | 6893.3 | 10A | beacon | 47°10'08.827" | 070°39'50.998" |
| Pointe Argentenay FR | 1910.5 | 8B | range light | 47°00'27.870" | 070°48'18.450" |
| Pointe Argentenay RR | 1910.6 | 8C | range light | 46°59'13.116" | 070°49'30.762" |
| *12-Foot Rock* Beacon | 6895.75 | 10A | beacon | 47°06'16.225" | 070°40'19.899" |
| K-096 | 1894 | 12A | 2.9-m bell buoy | 47°08'39.284" | 070°40'29.906" |
| K-096 | idem | 15A | 1.0-m spar | 47°08'39.284" | 070°40'29.906" |
| K-095 | 1895 | 12A | 2.9-m bell buoy | 47°08'04.806" | 070°40'46.146" |
| K-099 | 1895.8 | 12A | 2.9-m bell buoy | 47°06'53.421" | 070°41'55.698" |
| K-100 | 1895.9 | 12A | 2.9-m bell buoy | 47°06'38.929" | 070°42'27.186" |
| Cap Gribane FR | 1895.2 | 8C | range light | 47°08'27.244" | 070°41'08.788" |
| Cap Gribane RR | 1895.3 | 8C | range light | 47°08'40.433" | 070°41'00.237" |
| *Cap Tourmente* Beacon | 6903.2 | 10A | beacon | 47°05'16.994" | 070°44'35.038" |
| K-101 | 1895.91 | 12A | 2.9-m bell buoy | 47°06'15.852" | 070°42'26.307" |
| K-104 | 1897 | 12A | 2.9-m bell buoy | 47°05'14.933" | 070°43'21.537" |
| K-103 | 1896 | 12A | 2.9-m bell buoy | 47°05'10.941" | 070°43'08.309" |
| Banc Brûlé Racon | "1900" | 7A | racon | 47°05'22.548" | 070°42'38.850" |
| *Friponne* Beacon | 6905.3 | 10A | beacon | 47°04'18.907" | 070°47'06.945" |
| K-107 | 1904 | 12A | 2.9-m bell buoy | 47°03'46.184" | 070°44'03.106" |
| K-108 | 1905 | 12A | 2.9-m bell buoy | 47°03'50.929" | 070°44'15.841" |
| K-108 | idem | 15A | 1.0-m spar | 47°03'50.929" | 070°44'15.841" |
| FR Upbound from Cap Brûlé | 1900 | 8C | range light | 47°05'22.548" | 070°42'38.850" |
| RR Upbound from Cap Brûlé | 1901 | 8C | range light | 47°05'49.976" | 070°42'12.384" |
| *Décor* Beacon | 6910.3 | 10A | beacon | 47°01'20.016" | 070°47'46.611" |
| K-111 | 1906 | 12A | 2.9-m bell buoy | 47°02'31.844" | 070°45'14.737" |
| K-112 | 1908 | 12A | 2.9-m bell buoy | 47°02'37.275" | 070°45'26.806" |
| K-112 | idem | 15A | 1.0-m spar | 47°02'37.275" | 070°45'26.806" |
| K-115 | 1909 | 12A | 2.9-m bell buoy | 47°01'18.207" | 070°46'25.625" |
| K-116 | 1910 | 12A | 2.9-m bell buoy | 47°01'23.636" | 070°46'37.692" |
| K-116 | idem | 15A | 1.0-m spar | 47°01'23.636" | 070°46'37.692" |
| *East Ile Madame* Beacon | 6912.3 | 10A | beacon | 46°58'45.677" | 070°46'58.373" |
| *West Ile Madame* Beacon | 6913.6 | 10A | beacon | 46°57'41.188" | 070°48'10.385" |
| K-119 | 1911 | 12A | 2.9-m bell buoy | 47°00'04.557" | 070°47'36.459" |
| K-120 | 1912 | 12A | 2.9-m bell buoy | 47°00'09.984" | 070°47'48.523" |
| K-120 | 1912 | 15A | 1.0-m spar | 47°00'09.984" | 070°47'48.523" |
| St François WL | 1913 | 4C | wharf light | 46°59'47.578" | 070°48'29.496" |
| *Carré Beacon* | 6913.5 | 10A | beacon | 46°58'38.457" | 070°49'44.804" |
| St Michel FR | 1918 | 8C | range light | 46°52'31.008" | 070°54'59.790" |
| St Michel RR | 1919 | 8C | range light | 46°51'43.930" | 070°55'44.758" |
| K-123 | 1913.4 | 13A | 1.8-m NT | 46°58'50.900" | 070°48'47.234" |
| K-124 | 1912.8 | 13A | 1.8-m NT | 46°58'56.324" | 070°48'59.296" |
| K-127 | 1914 | 12A | 1.8-m moine | 46°57'37.231" | 070°49'57.955" |
| K-128 | 1915 | 12A | 2.9-m bell buoy | 46°57'42.654" | 070°50'10.013" |
| K-128 | idem | 15A | 1.0-m spar | 46°57'42.654" | 070°50'10.013" |
| *Gabriel* Beacon | 6917.7 | 10A | beacon | 46°56'15.755" | 070°52'21.254" |
| K-131 | 1916 | 12A | 2.9-m bell buoy | 46°56'41.704" | 070°50'51.217" |
| K-132 | 1917 | 12A | 2.9-m bell buoy | 46°56'45.475" | 070°51'04.856" |
| K-132 | idem | 15A | 1.0-m spar | 46°56'45.475" | 070°51'04.856" |
| K-135 | 1917.3 | 12A | 2.9-m bell buoy | 46°55'53.597" | 070°51'37.331" |
| DAME | 1922 | 12A | 2.9 m | 46°55'53.078" | 070°50'30.283" |
| K-136 | 1917.2 | 12A | 2.9-m bell buoy | 46°55'31.784" | 070°52'15.477" |
| K-136 | idem | 15A | 1.0-m spar | 46°55'31.784" | 070°52'15.477" |
| St Jean WL | 1923 | 4C | wharf light | 46°54'56.524" | 070°53'46.961" |
| St Jean Racon | "1923" | 7A | racon | 46°54'56.524" | 070°53'46.961" |

| | | | | Position in (NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| Cap Rouge FR | 1895.6 | 8C | range light | 47°07'30.038" | 070°42'06.041" |
| Cap Rouge RR | 1895.7 | 8C | range light | 47°07'05.055" | 070°42'38.078" |
| *Neptune Beacon* | 6893.2 | 10A | beacon | 47°09'42.422" | 070°36'27.866" |
| K-091 | 1893.5 | 12A | 2.9-m bell buoy | 47°09'16.179" | 070°39'36.524" |
| *Pointe d'Alliance Beacon* | 6893.3 | 10A | beacon | 47°10'08.827" | 070°39'50.998" |
| Pointe Argentenay FR | 1910.5 | 8B | range light | 47°00'27.870" | 070°48'18.450" |
| Pointe Argentenay RR | 1910.6 | 8C | range light | 46°59'13.116" | 070°49'30.762" |
| *12-Foot Rock Beacon* | 6895.75 | 10A | beacon | 47°06'16.225" | 070°40'19.899" |
| K-096 | 1894 | 12A | 2.9-m bell buoy | 47°08'39.284" | 070°40'29.906" |
| K-096 | idem | 15A | 1.0-m spar buoy | 47°08'39.284" | 070°40'29.906" |
| K-099 | 1895.8 | 12A | 2.9-m bell buoy | 47°06'53.421" | 070°41'55.698" |
| Cap Gribane FR | 1895.2 | 8C | range light | 47°08'27.244" | 070°41'08.788" |
| Cap Gribane RR | 1895.3 | 8C | range light | 47°08'40.433" | 070°41'00.237" |
| *Cap Tourmente Beacon* | 6903.2 | 10A | beacon | 47°05'16.994" | 070°44'38.038" |
| Banc Brûlé Racon | "1900" | 7A | racon | 47°05'22.548" | 070°42'38.850" |
| *Triponne Beacon* | 6905.3 | 10A | beacon | 47°04'18.907" | 070°47'06.945" |
| K-108 | 1905 | 12A | 2.9-m bell buoy | 47°03'50.929" | 070°44'15.841" |
| K-108 | idem | 15A | 1.0-m spar buoy | 47°03'50.929" | 070°44'15.841" |
| FR Upbound from Cap Brûlé | 1900 | 8C | range light | 47°05'22.548" | 070°42'38.850" |
| RR Upbound from Cap Brûlé | 1901 | 8C | range light | 47°05'49.976" | 070°42'12.384" |
| *Décor Beacon* | 6910.3 | 10A | beacon | 47°01'20.016" | 070°47'46.611" |
| K-112 | 1908 | 12A | 2.9-m bell buoy | 47°02'37.275" | 070°45'26.806" |
| K-112 | idem | 15A | 1.0-m spar buoy | 47°02'37.275" | 070°45'26.806" |
| K-115 | 1909 | 12A | 2.9-m bell buoy | 47°01'18.207" | 070°46'25.625" |
| *East Ile Madame Beacon* | 6912.3 | 10A | beacon | 46°58'45.677" | 070°46'58.373" |
| *West Ile Madame Beacon* | 6913.6 | 10A | beacon | 46°57'41.188" | 070°48'10.385" |
| K-120 | 1912 | 12A | 2.9-m bell buoy | 47°00'09.984" | 070°47'48.523" |
| K-120 | 1912 | 15A | 1.0-m spar buoy | 47°00'09.984" | 070°47'48.523" |
| St François WL | 1913 | 4C | wharf light | 46°59'47.578" | 070°48'29.496" |
| *Carré Beacon* | 6913.5 | 10A | beacon | 46°58'38.457" | 070°49'44.804" |
| St Michel FR | 1918 | 8C | range light | 46°52'31.008" | 070°54'59.790" |
| St Michel RR | 1919 | 8C | range light | 46°51'43.930" | 070°55'44.758" |
| K-128 | 1915 | 12A | 2.9-m bell buoy | 46°57'42.654" | 070°50'10.013" |
| K-128 | idem | 15A | 1.0-m spar buoy | 46°57'42.654" | 070°50'10.013" |
| *Gabriel Beacon* | 6917.7 | 10A | beacon | 46°56'15.755" | 070°52'21.254" |
| K-132 | 1917 | 12A | 2.9-m bell buoy | 46°56'45.475" | 070°51'04.856" |
| K-132 | idem | 15A | 1.0-m spar buoy | 46°56'45.475" | 070°51'04.856" |
| K-135 | 1917.3 | 12A | 2.9-m bell buoy | 46°55'53.597" | 070°51'37.331" |
| DAME | 1922 | 12A | 2.9 m | 46°55'53.078" | 070°50'30.283" |
| K-136 | 1917.2 | 12A | 2.9-m bell buoy | 46°55'31.784" | 070°52'15.477" |
| K-136 | idem | 15A | 1.0-m spar buoy | 46°55'31.784" | 070°52'15.477" |
| St Jean WL | 1923 | 4C | wharf light | 46°54'56.524" | 070°53'46.961" |
| St Jean Racon | "1923" | 7A | racon | 46°54'56.524" | 070°53'46.961" |

| | | | | Position (in NAD '83) | | |
|---|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude | |
| C-52 | 2093.3 | 13A | 1.8-m NT | 46°20' 42.742" | 072°31' 36.620" | |
| C-53 | 2094 | 13A | 1.8-m NT | 46°20' 29.3" | 072°31' 04.5" | |
| C-53 | idem | 15A | 0.7-m spar buoy | 46°20' 29.3" | 072°31' 04.5" | |
| C-57 | 2097 | 13A | 1.8-m NT | 46°20' 07.3" | 072°31' 40.8" | |
| St Angèle de Laval FR | 2092 | 8C | range light | 46° 18' 48.272" | 072° 33' 59.932" | |
| St Angèle de Laval RR | 2093 | 8C | range light | 46° 18' 43.396" | 072° 34' 09.337" | |
| C-61 | 2099 | 13A | 1.8-m NT | 46° 19' 45.19" | 072° 32' 17.399" | |
| C-61 | idem | 15A | 0.7-m spar buoy | 46° 19' 45.19" | 072° 32' 17.399" | |
| C-63 | 2104.2 | 13A | 1.8-m NT | 46° 19' 22.134" | 072° 32' 44.637" | |
| C-63 | idem | 15A | 0.7-m spar buoy | 46° 19' 22.134" | 072° 32' 44.637" | |
| C-65 | 2104.6 | 13A | 1.8-m NT | 46° 18' 48.685" | 072° 33' 08.349" | |
| C-65 | idem | 15A | 0.7-m spar buoy | 46° 18' 48.685" | 072° 33' 08.349" | |
| Bridge Lights | PRIVATE-SECTOR | N. A. | | | | |
| "I" Racon | 7105.72 | 7A | racon | 46° 18' 30" | 072° 33' 48" | |
| "H" Racon | 7105.73 | 7A | racon | 46° 18' 23" | 072° 33' 39" | |
| C-67 | 2106 | 13A | 1.8-m NT | 46° 18' 15.797" | 072° 33' 48.290" | |
| C-67 | idem | 15A | 0.7-m spar buoy | 46° 18' 15.797" | 072° 33' 48.290" | |
| C-68 | 2105 | 13A | 1.8-m NT | 46° 18' 20.5" | 072° 33' 56.3" | |
| C-70 | 2108 | 13A | 1.8-m NT | 46° 18' 05.365" | 072° 34' 36.139" | |
| C-71 | 2109 | 13B | 1.8-m NT | 46°17'25.876" | 072°34'59.453" | |
| C-72 | 2109.1 | 13A | 1.8-m NT | 46°17'38.596" | 072°35'25.484" | |
| C-72 | idem | 15A | 0.7-m spar buoy | 46°17'38.596" | 072°35'25.484" | |
| TRV-A | 2109.5 | 13B | 1.8-m NT | 46°17'12.1" | 72°36'25.1" | |
| C-77 | 2109.6 | 13A | 1.8-m NT | 46°16'42.664" | 072°36'35.647" | |
| C-77 | idem | 15A | 0.7-m spar buoy | 46°16'42.664" | 072°36'35.647" | |
| Siemes '85 Beacon | 7109.7 | 10A | beacon | 46°17'32.926" | 072°37'14.456" | |
| Marais Beacon | 7109.8 | 10A | beacon | 46°17'15.998" | 072°38'17.676" | |
| Port St François WL | 2111 | 4A | wharf light | 46°16'20.523" | 072°37'09.576" | |
| S-002 | 2110 | 13A | 1.8-m NT | 46°16'29.950" | 072°37'22.366" | |
| S-003 | 2114.5 | 13A | 1.8-m NT | 46°15'58.061" | 072°37'58.172" | |
| S-004 | 2114 | 13A | 1.8-m NT | 46°16'06.711" | 072°38'05.342" | |
| S-004 | idem | 15A | 0.7-m spar buoy | 46°16'06.711" | 072°38'05.342" | |
| St François FR | 2112 | 8C | range light | 46°16'16.493" | 072°37'10.897" | |
| St François RR | 2113 | 8C | range light | 46°16'32.988" | 072°36'11.391" | |
| S-006 | 2118.5 | 13A | 1.8 m | 46°15'56.517" | 072°38'42.016" | |
| S-006 | idem | 15A | 0.7-m spar buoy | 46°15'56.517" | 072°38'42.016" | |
| Racon | "2119.5" | 7A | racon | 46°15'27.094" | 072°39'03.456" | |
| Nicolet Sector Lights | 2119.5 | 9C | sector light | 46°15'27.094" | 072°39'03.456" | |
| S-008 | 2119 | 13A | 1.8-m NT | 46°15'50.821" | 072°39'16.723" | |
| S-008 | idem | 15A | 0.7-m spar buoy | 46°15'50.821" | 072°39'16.723" | |
| S-009 | 2120 | 13A | 1.8-m NT | 46°15'32.7" | 072°39'30.5" | → NAD '27 |
| Nicolet Traverse FR | 2117 | 8B | range light | 46°15'34.949" | 072°37'48.366" | |
| Nicolet Traverse RR | 2118 | 8C | range light | 46°15'32.730" | 072°37'21.312" | |
| S-010 | 2120.5 | 13A | 1.8-m NT | 46°15'50.035" | 072°39'52.370" | |
| S-010 | idem | 15A | 0.7-m spar buoy | 46°15'50.035" | 072°39'52.370" | |
| Canon Beacon | N. A. | 10A | beacon | 46°13'33.011" | 072°40'17.517" | |
| S-013 | 2122 | 13A | 1.8 m | 46°15'43.516" | 072°40'34.390" | |
| S-012 | 2121 | 13A | 1.8-m NT | 46°15'53.929" | 072°40'40.115" | |
| S-012 | idem | 15A | 0.7-m spar buoy | 46°15'53.929" | 072°40'40.115" | |
| S-017 | 2123 | 13A | 1.8 m | 46°15'44.928" | 072°41'09.978" | |
| S-016 | 2122.8 | 13A | 1.8-m NT | 46°15'57.817" | 072°41'27.861" | |
| S-016 | idem | 15A | 0.7-m spar buoy | 46°15'57.817" | 072°41'27.861" | |
| LAC | 2123.5 | 16A | R.R. buoy | 46°16'03.114" | 072°41'43.426" | |
| S-021 | 2124 | 13A | 1.8 m | 46°15'42.641" | 072°41'49.059" | |
| S-022 | 2127 | 13A | 1.8-m NT | 46°15'54.576" | 072°42'02.816" | |
| S-022 | idem | 15A | 0.7-m spar buoy | 46°15'54.576" | 072°42'02.816" | |
| S-025 | 2128 | 13A | 1.8-m NT | 46°15'35.470" | 072°42'27.226" | |
| S-026 | 2129 | 13A | 1.8-m NT | 46°15'40.581" | 072°42'46.936" | |
| S-026 | idem | 15A | 0.7-m spar buoy | 46°15'40.581" | 072°42'46.936" | |
| Glaises Beacon | 7127.7 | 10A | beacon | 46°17'29.631" | 072°43'46.196" | |
| Pointe du Lac FR | 2125 | 8C | range light | 46°16'05.496" | 072°41'43.219" | |
| Pointe du Lac POS | 2125 | 4C | shore light | 46°16'05.496" | 072°41'43.219" | |
| Pointe du Lac RR | 2126 | 8C | range light | 46°16'46.347" | 072°40'15.433" | |
| S-027 | 2129.3 | 13A | 1.8 m | 46°15'24.971" | 072°42'59.921" | |
| S-031 | 2129.6 | 13A | 1.8-m NT | 46°14'36.868" | 072°44'43.092" | → Moved |
| S-032 | 2130 | 13A | 1.8-m NT | 46°14'43.453" | 072°44'49.474" | Moved |
| S-032 | idem | 15A | 0.7-m spar buoy | 46°14'43.453" | 072°44'49.474" | |
| S-041 | 2131.4 | 13A | 1.4 m | 46°14'17.2" | 072°45'26.5" | → NAD '27 |
| S-042 | 2131.5 | 13A | 1.8-m NT. | 46°14'23.8" | 072°45'32.9" | → NAD '27 |
| S-042 | idem | 15A | 0.7-m spar buoy | 46°14'23.8" | 072°45'32.9" | → NAD '27 |
| West Yamachiche Turn FR | 2137.2 | 8C | range light | 46°12'18.698" | 072°49'49.129" | |
| West Yamachiche Turn POS | 2137.2 | 4C | shore light | 46°12'18.698" | 072°49'49.129" | |
| West Yamachiche Turn RR | 2137.3 | 8C | range light | 46°12'04.913" | 072°50'18.575" | |
| Racon | "2137.2" | 7A | racon | 46°12'18.698" | 072°49'49.129" | |
| Gignac Beacon | 7132.3 | 10A | beacon | 46°15'54.575" | 072°47'59.680" | |
| S-043 | 2131.7 | 13A | 1.8-m NT | 46°13'48.738" | 072°46'26.213" | → Moved |
| S-044 | 2132 | 13A | 1.8-m NT | 46°13'55.322" | 072°46'32.497" | Moved |
| S-044 | idem | 15A | 0.7-m spar buoy | 46°13'55.322" | 072°46'32.497" | |
| S-054 | 2134 | 13A | 1.8-m NT | 46°13'07.165" | 072°48'15.670" | |
| S-054 | idem | 15A | 0.7-m spar buoy | 46°13'07.165" | 072°48'15.670" | |
| S-051 | 2133 | 13A | 1.8-m NT | 46°12'55.620" | 072°48'19.901" | |
| Yamachiche Turn FR | 2134.8 | 4C | shore light | 46°12'52.990" | 072°49'10.035" | |
| S-058 | 2135 | 13B | 1.8-m NT | 46°12'48.713" | 072°49'07.886" | |
| YAM-A | 2133.2 | 13B | 1.8-m NT | 46°12'37.9" | 072°48'29.7" | → NAD '27 |
| YAM-B | 2133.21 | 13B | 1.8-m NT | 46°12'29.035" | 072°48'53.454" | |

| | | | | Position (in NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| C-52 | 2093.3 | 13A | 1.80-m NT | 46°20' 42.742" | 072°31' 36.620" |
| C-57 | 2097 | 13A | 1.80-m NT | 46°20' 07.3" | 072°31' 40.8" |
| St Angèle de Laval FR | 2092 | 8C | range light | 46° 18' 48.272" | 072° 33' 59.932" |
| St Angèle de Laval RR | 2093 | 8C | range light | 46° 18' 43.396" | 072° 34' 09.337" |
| C-61 | 2099 | 13A | 1.80-m NT | 46° 19' 45.19" | 072° 32' 17.399" |
| C-61 | idem | 15A | 0.7-m spar buoy | 46° 19' 45.19" | 072° 32' 17.399" |
| C-63 | 2104.2 | 13A | 1.80-m NT | 46° 19' 22.134" | 072° 32' 44.637" |
| C-63 | idem | 15A | 0.7-m spar buoy | 46° 19' 22.134" | 072° 32' 44.637" |
| C-65 | 2104.6 | 13A | 1.80-m NT | 46° 18' 48.685" | 072° 33' 08.349" |
| C-65 | idem | 15A | 0.7-m spar buoy | 46° 18' 48.685" | 072° 33' 08.349" |
| Bridge Lights | PRIVATE SECTOR | N. A. | | | |
| "T" Racon | 7105.72 | 7A | racon | 46° 18' 30" | 072° 33' 48" |
| "H" Racon | 7105.73 | 7A | racon | 46° 18' 23" | 072° 33' 39" |
| C-67 | 2106 | 13A | 1.80-m NT | 46° 18' 15.797" | 072° 33' 48.290" |
| C-67 | idem | 15A | 0.7-m spar buoy | 46° 18' 15.797" | 072° 33' 48.290" |
| C-70 | 7108 | 13B | 0.7-m spar buoy | 46° 18' 05.365" | 072° 34' 36.139" |
| C-71 | 2109 | 13B | 1.80-m NT | 46°17'25.876" | 072°34'59.453" |
| C-72 | 2109.1 | 13A | 1.80-m NT | 46°17'38.596" | 072°35'25.484" |
| C-72 | idem | 15A | 0.7-m spar buoy | 46°17'38.596" | 072°35'25.484" |
| C-77 | 2109.6 | 13A | 1.80-m NT | 46°16'42.664" | 072°36'35.647" |
| C-77 | idem | 15A | 0.7-m spar buoy | 46°16'42.664" | 072°36'35.647" |
| *Stemes '85* Beacon | 7109.7 | 10A | beacon | 46°17'32.926" | 072°37'14.456" |
| *Marais* Beacon | 7109.8 | 10A | beacon | 46°17'15.998" | 072°38'17.676" |
| Port St François WL | 2111 | 4A | wharf light | 46°16'20.523" | 072°37'09.576" |
| S-002 | 2110 | 13A | 1.80-m NT | 46°16'29.950" | 072°37'22.366" |
| S-003 | 2114.5 | 13A | 1.80-m NT | 46°15'58.061" | 072°37'58.172" |
| S-004 | 2114 | 13A | 1.80-m NT | 46°16'06.711" | 072°38'05.342" |
| S-004 | idem | 15A | 0.7-m spar buoy | 46°16'06.711" | 072°38'05.342" |
| St François FR | 2112 | 8C | range light | 46°16'16.493" | 072°37'10.897" |
| St François RR | 2113 | 8C | range light | 46°16'32.988" | 072°36'11.391" |
| S-006 | 2118.5 | 13A | 1.8 m | 46°15'56.517" | 072°38'42.016" |
| S-006 | idem | 15A | 0.7-m spar buoy | 46°15'56.517" | 072°38'42.016" |
| Racon | "2119.5" | 7A | racon | 46°15'27.094" | 072°39'03.456" |
| Nicolet Sector Lights | 2119.5 | 9C | sector light | 46°15'27.094" | 072°39'03.456" |
| S-008 | 2119 | 13A | 1.80-m NT | 46°15'50.821" | 072°39'16.723" |
| S-008 | idem | 15A | 0.7-m spar buoy | 46°15'50.821" | 072°39'16.723" |
| Nicolet Traverse FR | 2117 | 8B | range light | 46°15'34.949" | 072°37'48.366" |
| Nicolet Traverse RR | 2118 | 8C | range light | 46°15'32.730" | 072°37'21.312" |
| S-010 | 2120.5 | 13A | 1.80-m NT | 46°15'50.035" | 072°39'52.370" |
| S-010 | idem | 15A | 0.7-m spar buoy | 46°15'50.035" | 072°39'52.370" |
| *Canon* Beacon | N. A. | 10A | beacon | 46°13'33.011" | 072°40'17.517" |
| S-013 | 2122 | 13A | 1.8 m | 46°15'43.516" | 072°40'34.390" |
| S-012 | 2121 | 13A | 1.80-m NT | 46°15'53.929" | 072°40'40.115" |
| S-012 | idem | 15A | 0.7-m spar buoy | 46°15'53.929" | 072°40'40.115" |
| S-017 | 2123 | 13A | 1.8 m | 46°15'44.928" | 072°41'09.978" |
| S-016 | 2122.8 | 13A | 1.80-m NT | 46°15'57.817" | 072°41'27.861" |
| S-016 | idem | 15A | 0.7-m spar buoy | 46°15'57.817" | 072°41'27.861" |
| LAC | 2123.5 | 16A | R.R. buoy | 46°16'03.114" | 072°41'43.426" |
| S-021 | 2124 | 13A | 1.8 m | 46°15'42.641" | 072°41'49.059" |
| S-022 | 2127 | 13A | 1.80-m NT | 46°15'54.576" | 072°42'02.816" |
| S-022 | idem | 15A | 0.7-m spar buoy | 46°15'54.576" | 072°42'02.816" |
| S-025 | 2128 | 13A | 1.80-m NT | 46°15'35.470" | 072°42'27.226" |
| S-026 | 2129 | 13A | 1.80-m NT | 46°15'40.581" | 072°42'46.936" |
| S-026 | idem | 15A | 0.7-m spar buoy | 46°15'40.581" | 072°42'46.936" |
| *Glaises* Beacon | 7127.7 | 10A | beacon | 46°17'29.631" | 072°43'46.196" |
| Pointe du Lac FR | 2125 | 8C | range light | 46°16'05.496" | 072°41'43.219" |
| Pointe du Lac POS | 2125 | 4C | shore light | 46°16'05.496" | 072°41'43.219" |
| Pointe du Lac RR | 2126 | 8C | range light | 46°16'46.347" | 072°40'15.433" |
| S-027 | 2129.3 | 13A | 1.8 m | 46°15'24.971" | 072°42'59.921" |
| S-031 | 2129.6 | 13A | 1.80-m NT | 46°14'36.868" | 072°44'43.092" |
| S-032 | 2130 | 13A | 1.80-m NT | 46°14'43.453" | 072°44'49.474" |
| S-032 | idem | 15A | 0.7-m spar buoy | 46°14'43.453" | 072°44'49.474" |
| West Yamachiche Turn FR | 2137.2 | 8C | range light | 46°12'18.698" | 072°49'49.129" |
| West Yamachiche Turn POS | 2137.2 | 4C | shore light | 46°12'18.698" | 072°49'49.129" |
| West Yamachiche Turn RR | 2137.3 | 8C | range light | 46°12'04.913" | 072°50'18.575" |
| Racon | "2137.2" | 7A | racon | 46°12'18.698" | 072°49'49.129" |
| *Gignac* Beacon | 7132.3 | 10A | beacon | 46°15'54.575" | 072°47'59.680" |
| S-043 | 2131.7 | 13A | 1.80-m NT | 46°13'48.738" | 072°46'26.213" |
| S-044 | 2132 | 13A | 1.80-m NT | 46°13'55.322" | 072°46'32.497" |
| S-044 | idem | 15A | 0.7-m spar buoy | 46°13'55.322" | 072°46'32.497" |
| S-054 | 2134 | 13A | 1.80-m NT | 46°13'07.165" | 072°48'15.670" |
| S-054 | idem | 15A | 0.7-m spar buoy | 46°13'07.165" | 072°48'15.670" |
| S-051 | 2133 | 13A | 1.80-m NT | 46°12'55.620" | 072°48'19.901" |
| Yamachiche Turn FR | 2134.8 | 4C | shore light | 46°12'52.990" | 072°49'10.035" |
| S-058 | 7135 | 13B | 0.7-m spar buoy | 46°12'48.713" | 072°49'07.886" |
| YAM-B | 7133.21 | 13B | 0.7-m spar buoy | 46°12'29.035" | 072°48'53.454" |

| Identification | # L. F. | Category | Type | Position (In NAD '83) Latitude | Longitude | |
|---|---|---|---|---|---|---|
| C-57 | 2097 | 13A | 1.8-m NT | 46°20' 07.3" | 072°31' 40.8" | |
| St Angèle de Laval FR | 2092 | 8C | range light | 46° 18' 48.272" | 072° 33' 59.932" | |
| St Angèle de Laval RR | 2093 | 8C | range light | 46° 18' 43.396" | 072° 34' 09.337" | |
| C-61 | 2099 | 13A | 1.8-m NT | 46° 19' 45.19" | 072° 32' 17.399" | |
| C-61 | idem | 15A | 0.7-m spar buoy | 46° 19' 45.19" | 072° 32' 17.399" | |
| C-63 | 2104.2 | 13A | 1.8-m NT | 46° 19' 22.134" | 072° 32' 44.637" | |
| C-63 | idem | 15A | 0.7-m spar buoy | 46° 19' 22.134" | 072° 32' 44.637" | |
| C-65 | 2104.6 | 13A | 1.8-m NT | 46° 18' 48.685" | 072° 33' 08.349" | |
| C-65 | idem | 15A | 0.7-m spar buoy | 46° 18' 48.685" | 072° 33' 08.349" | |
| Bridge Lights | *PRIVATE SECTOR* | N. A. | | | | |
| "I" Racon | 7105.72 | 7A | racon | 46° 18' 30" | 072° 33' 48" | |
| "H" Racon | 7105.73 | 7A | racon | 46° 18' 23" | 072° 33' 39" | |
| C-77 | 2109.6 | 13A | 1.8-m NT | 46°16'42.664" | 072°36'35.647" | |
| C-77 | idem | 15A | 0.7-m spar buoy | 46°16'42.664" | 072°36'35.647" | |
| Stemes '85 Beacon | 7109.7 | 10A | beacon | 46°17'32.926" | 072°37'14.456" | |
| Marais Beacon | 7109.8 | 10A | beacon | 46°17'15.996" | 072°38'17.676" | |
| Port St François WL | 2111 | 4A | wharf light | 46°16'20.523" | 072°37'09.576" | |
| S-003 | 2114.5 | 13A | 1.8-m NT | 46°15'58.061" | 072°37'58.172" | |
| S-004 | 2114 | 13A | 1.8-m NT | 46°16'06.711" | 072°38'05.342" | |
| S-004 | idem | 15A | 0.7-m spar buoy | 46°16'06.711" | 072°38'05.342" | |
| St François FR | 2112 | 8C | range light | 46°16'16.493" | 072°37'10.897" | |
| St François RR | 2113 | 8C | range light | 46°16'32.988" | 072°36'11.391" | |
| Racon | "2119.5" | 7A | racon | 46°15'27.094" | 072°39'03.456" | |
| Nicolet Sector Lights | 2119.5 | 9C | sector light | 46°15'27.094" | 072°39'03.456" | |
| S-008 | 2119 | 13A | 1.8-m NT | 46°15'50.821" | 072°39'16.723" | |
| S-008 | idem | 15A | 0.7-m spar buoy | 46°15'50.821" | 072°39'16.723" | |
| S-009 | 2120 | 13A | 1.8-m NT | 46°15'32.7" | 072°39'30.5" | → NAD '27 |
| Nicolet Traverse FR | 2117 | 8B | range light | 46°15'34.949" | 072°37'48.366" | |
| Nicolet Traverse RR | 2118 | 8C | range light | 46°15'32.730" | 072°37'21.312" | |
| Canari Beacon | N. A. | 10A | beacon | 46°13'33.011" | 072°40'17.517" | |
| S-017 | 2123 | 13A | 1.8 m | 46°15'44.928" | 072°41'09.978" | |
| S-016 | 2122.8 | 13A | 1.8-m NT | 46°15'57.817" | 072°41'27.861" | |
| S-016 | idem | 15A | 0.7-m spar buoy | 46°15'57.817" | 072°41'27.861" | |
| S-021 | 2124 | 13A | 1.8 m | 46°15'42.641" | 072°41'49.059" | |
| S-022 | 2127 | 13A | 1.8-m NT | 46°15'54.576" | 072°42'02.816" | |
| S-022 | idem | 15A | 0.7-m spar buoy | 46°15'54.576" | 072°42'02.816" | |
| S-026 | 2129 | 13A | 1.8-m NT | 46°15'40.581" | 072°42'46.936" | |
| S-026 | idem | 15A | 0.7-m spar buoy | 46°15'40.581" | 072°42'46.936" | |
| Glaises Beacon | 7127.7 | 10A | beacon | 46°17'29.631" | 072°43'46.196" | |
| Pointe du Lac FR | 2125 | 8C | range light | 46°16'05.496" | 072°41'43.219" | |
| Pointe du Lac POS | 2125 | 4C | shore light | 46°16'05.496" | 072°41'43.219" | |
| Pointe du Lac RR | 2126 | 8C | range light | 46°16'46.347" | 072°40'15.433" | |
| S-027 | 2129.3 | 13A | 1.8 m | 46°15'24.971" | 072°42'59.921" | |
| S-041 | 2131.4 | 13A | 1.4 m | 46°14'17.2" | 072°45'26.5" | → NAD '27 |
| S-042 | 2131.5 | 13A | 1.8-m NT | 46°14'23.8" | 072°45'32.9" | → NAD '27 |
| S-042 | idem | 15A | 0.7-m spar buoy | 46°14'23.8" | 072°45'32.9" | → NAD '27 |
| West Yamachiche Turn FR | 2137.2 | 8C | range light | 46°12'18.698" | 072°49'49.129" | |
| West Yamachiche Turn POS | 2137.2 | 4C | shore light | 46°12'18.698" | 072°49'49.129" | |
| West Yamachiche Turn RR | 2137.3 | 8C | range light | 46°12'04.913" | 072°50'18.575" | |
| Racon | "2137.2" | 7A | racon | 46°12'18.698" | 072°49'49.129" | |
| Gignac Beacon | 7132.3 | 10A | beacon | 46°15'54.575" | 072°47'59.680" | |
| S-054 | 2134 | 13A | 1.8-m NT | 46°13'07.165" | 072°48'15.670" | |
| S-054 | idem | 15A | 0.7-m spar buoy | 46°13'07.165" | 072°48'15.670" | |
| S-051 | 2133 | 13A | 1.8-m NT | 46°12'55.620" | 072°48'19.901" | |
| Yamachiche Turn FR | 2134.8 | 4C | shore light | 46°12'52.990" | 072°49'10.035" | |
| YAM-B | 7133.21 | 13B | 0.7-m spar buoy | 46°12'29.035" | 072°48'53.454" | |

| | | | | Position (in NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| | | | | | |
| Anse aux Basques | 1754 | 7A | racon | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques | 1754 | 4C | shore light | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques FR | 1754.2 | 8B | range light | 48° 19' 05.28" | 69° 24' 50.96" |
| Anse aux Basques RR | 1754.3 | 8B | range light | 48° 19' 06.46" | 69° 24' 53.812" |
| Cap Bon Désir | 1755 | 4C | shore light | 48° 16' 19.462" | 69° 28' 07.231" |
| East Escoumins FR | 1754.7 | 8B | range light | 48° 16' 20.510" | 69° 29, 23.009" |
| East Escoumins RR | 1754.8 | 8B | range light | 48° 16' 31.861" | 69° 29' 43.237" |
| West Escoumins FR | 1755.5 | 8B | range light | 48° 15' 33.391" | 69° 30' 18.683" |
| West Escoumins RR | 1755.6 | 8B | range light | 48° 15' 40.281" | 69° 30' 30.968" |
| K-51 | 1766.8 | 12A | 2.9-m bell buoy | 48° 06' 53.08" | 069° 31' 03.178" |
| K-55 | 1766 | 12A | 2.9-m bell buoy | 48° 05' 37.845" | 069° 33' 58.891" |
| Île Rouge | 1770 | 4C | shore light | 48° 04' 09.983" | 69° 33' 16.939" |
| K-58 | 1771 | 12A | 2.9-m bell buoy | 48° 03' 30.075" | 069° 38' 36.188" |
| K-58 | idem | 15A | 1.0-m cone | 48° 03' 30.075" | 069° 38' 36.188" |
| K-56 | 1772 | 12A | 2.9-m bell buoy | 48° 04' 54.076" | 069° 37' 22.187" |
| Prince Shoal | 1773 | 4C | shore light | 48° 06' 29.643" | 69° 36' 51.685" |
| idem | idem | 6A | fog signal | 48° 06' 29.643" | 69° 36' 51.685" |
| *Saguenay* | 1774 | 12A | 2.9-m bell buoy | 48° 07' 08.815" | 069° 36' 05.467" |
| K-54 | 1774.3 | 12A | 2.9-m bell buoy | 48° 07' 48.584" | 069° 35' 56.932" |
| K-59 | 1823.8 | 12A | 2.9-m bell buoy | 47° 59' 06.076" | 069° 37' 52.183" |
| Cap de la Tête au Chien | 1834 | 4C | shore light | 47° 54' 41.519" | 69° 48' 23.748" |
| idem | idem | 6A | fog signal | 47° 54' 41.519" | 69° 48' 23.748" |
| | | | | | |
| S-3 | 1774.5 | 12A | 2.9-m bell buoy | 48° 06' 47" | 69° 37' 52" |
| S-4 | 1775 | 12A | 2.9-m bell buoy | 48° 07' 24.076" | 69° 37' 58.19" |
| S-4 | 1775 | 15A | 1.0-m cone | 48° 07' 24.076" | 69° 37' 58.19" |
| S-5 | 1776 | 12A | 2.9-m bell buoy | 48° 06' 59.918" | 69° 39' 15.841" |
| S-7 | 1778 | 12A | 2.9-m bell buoy | 48° 07' 11.075" | 69° 40' 30.194" |
| S-8 | 1777 | 12A | 2.9-m bell buoy | 48° 07' 30.075" | 69° 40' 17.194" |
| Pointe Noire FR | 1779 | 8C | range light | 48° 07' 23.909" | 69° 43' 00.412" |
| idem | idem | 6A | fog signal | 48° 07' 23.909" | 69° 43' 00.412" |
| Pointe Noire FR | 1780 | 8C | range light | 48° 07' 24.652" | 69° 43' 21.049" |
| Tadoussac SL | 1782 | 4C | shore light | 48° 08' 15.003" | 69° 42' 49.900" |
| Anse du Portage SL | 1784.5 | 4B | shore light | 48° 07' 36.658" | 69° 43' 49.608" |
| Pointe de l'Islet SL | 1783 | 4C | shore light | 48° 08' 07.297" | 69° 42' 59.396" |
| Anse à l'Eau SL | 1784 | 4B | shore light | 48° 08' 19.669" | 69° 43' 38.381" |
| Îlet aux Alouettes Beacon | 6778.2 | 10A | beacon | 48° 06' 28.403" | 69° 41' 02.157" |
| Moulin à Baude Beacon | 6775.8 | 10A | beacon | 48° 09' 34.042" | 69° 39' 51.376" |
| | | | | | |
| H-50 | 1767 | 12A | 2.9-m bell buoy | 48° 06' 26" | 69° 29' 38" |
| H-52 | 1769 | 12A | 2.9-m bell buoy | 48° 04' 31.079" | 69° 31' 39.176" |
| Île Verte SL | 1761 | 4C | shore light | 48° 03' 03.888" | 69° 25' 27.274" |

| | | | | Position (in NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| | | | | | |
| Anse aux Basques | 1754 | 7A | racon | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques | 1754 | 4C | shore light | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques FR | 1754.2 | 8B | range light | 48° 19' 05.28" | 69° 24' 50.96" |
| Anse aux Basques RR | 1754.3 | 8B | range light | 48° 19' 06.46" | 69° 24' 53.812" |
| Cap Bon Désir | 1755 | 4C | shore light | 48° 16' 19.462" | 69° 28' 07.231" |
| East Escoumins FR | 1754.7 | 8B | range light | 48° 16' 20.510" | 69° 29, 23.009" |
| East Escoumins RR | 1754.8 | 8B | range light | 48° 16' 31.861" | 69° 29' 43.237" |
| West Escoumins FR | 1755.5 | 8B | range light | 48° 15' 33.391" | 69° 30' 18.683" |
| West Escoumins RR | 1755.6 | 8B | range light | 48° 15' 40.281" | 69° 30' 30.968" |
| K-51 | 1766.8 | 12A | 2.9-m bell buoy | 48° 06' 53.08" | 069° 31' 03.178" |
| K-55 | 1766 | 12A | 2.9-m bell buoy | 48° 05' 37.845" | 069° 33' 58.891" |
| Île Rouge | 1770 | 4C | shore light | 48° 04' 09.983" | 69° 33' 16.939" |
| K-58 | 1771 | 12A | 2.9-m bell buoy | 48° 03' 30.075" | 069° 38' 36.188" |
| K-58 | idem | 15A | 1.0-m cone | 48° 03' 30.075" | 069° 38' 36.188" |
| K-56 | 1772 | 12A | 2.9-m bell buoy | 48° 04' 54.076" | 069° 37' 22.187" |
| Prince Shoal | 1773 | 4C | shore light | 48° 06' 29.643" | 69° 36' 51.685" |
| idem | idem | 6A | fog signal | 48° 06' 29.643" | 69° 36' 51.685" |
| *Saguenay* | 1774 | 12A | 2.9-m bell buoy | 48° 07' 08.815" | 069° 36' 05.467" |
| K-54 | 1774.3 | 12A | 2.9-m bell buoy | 48° 07' 48.584" | 069° 35' 56.932" |
| K-59 | 1823.8 | 12A | 2.9-m bell buoy | 47° 59' 06.076" | 069° 37' 52.183" |
| Cap de la Tête au Chien | 1834 | 4C | shore light | 47° 54' 41.519" | 69° 48' 23.748" |
| | | | | | |
| S-3 | 1774.5 | 12A | 2.9-m bell buoy | 48° 06' 47" | 69° 37' 52" |
| S-4 | 1775 | 12A | 2.9-m bell buoy | 48° 07' 24.076" | 69° 37' 58.19" |
| S-4 | 1775 | 15A | 1.0-m cone | 48° 07' 24.076" | 69° 37' 58.19" |
| S-5 | 1776 | 12A | 2.9-m bell buoy | 48° 06' 59.918" | 69° 39' 15.841" |
| S-7 | 1778 | 12A | 2.9-m bell buoy | 48° 07' 11.075" | 69° 40' 30.194" |
| S-8 | 1777 | 12A | 2.9-m bell buoy | 48° 07' 30.075" | 69° 40' 17.194" |
| Pointe Noire FR | 1779 | 8C | range light | 48° 07' 23.909" | 69° 43' 00.412" |
| idem | idem | 6A | fog signal | 48° 07' 23.909" | 69° 43' 00.412" |
| Pointe Noire RR | 1780 | 8C | range light | 48° 07' 24.652" | 69° 43' 21.049" |
| Anse du Portage SL | 1784.5 | 4B | shore light | 48° 07' 36.658" | 69° 43' 49.608" |
| Pointe de l'Islet SL | 1783 | 4C | shore light | 48° 08' 07.297" | 69° 42' 59.396" |
| Anse à l'Eau SL | 1784 | 4B | shore light | 48° 08' 19.669" | 69° 43' 38.381" |
| Îlet aux Alouettes Beacon | 6778.2 | 10A | beacon | 48° 06' 28.403" | 69° 41' 02.157" |
| Moulin à Baude Beacon | 6775.8 | 10A | beacon | 48° 09' 34.042" | 69° 39' 51.376" |
| | | | | | |
| H-52 | 1769 | 12A | 2.9-m bell buoy | 48° 04' 31.079" | 69° 31' 39.176" |
| Île Verte SL | 1761 | 4C | shore light | 48° 03' 03.888" | 69° 25' 27.274" |

| | | | | Position (in NAD '83) | |
|---|---|---|---|---|---|
| Identification | Light List # | Category | Type | Latitude | Longitude |
| | | | | | |
| Anse aux Basques | 1754 | 7A | racon | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques | 1754 | 4C | shore light | 48°19' 07.45 | 69° 24' 46.53" |
| Anse aux Basques FR | 1754.2 | 8B | range light | 48° 19' 05.28" | 69° 24' 50.96" |
| Anse aux Basques RR | 1754.3 | 8B | range light | 48° 19' 06.46" | 69° 24' 53.812" |
| Île Rouge | 1770 | 4C | shore light | 48° 04' 09.983" | 69° 33' 16.939" |
| K-58 | 1771 | 12A | 2.9-m bell buoy | 48° 03' 30.075" | 069° 38' 36.188" |
| K-58 | idem | 15A | 1.0-m cone | 48° 03' 30.075" | 069° 38' 36.188" |
| Prince Shoal | 1773 | 4C | shore light | 48° 06' 29.643" | 69° 36' 51.685" |
| idem | idem | 6A | fog signal | 48° 06' 29.643" | 69° 36' 51.685" |
| | | | | | |
| S-4 | 1775 | 12A | 2.9-m bell buoy | 48° 07' 24.076" | 69° 37' 58.19" |
| S-4 | 1775 | 15A | 1.0-m cone | 48° 07' 24.076" | 69° 37' 58.19" |
| Pointe Noire FR | 1779 | 8C | range light | 48° 07' 23.909" | 69° 43' 00.412" |
| idem | idem | 6A | fog signal | 48° 07' 23.909" | 69° 43' 00.412" |
| Pointe Noire RR | 1780 | 8C | range light | 48° 07' 24.652" | 69° 43' 21.049" |
| Anse du Portage SL | 1784.5 | 4B | shore light | 48° 07' 36.658" | 69° 43' 49.608" |
| Anse à l'Eau SL | 1784 | 4B | shore light | 48° 08' 19.669" | 69° 43' 38.381" |
| Îlet aux Alouettes Beacon | 6778.2 | 10A | beacon | 48° 06' 28.403" | 69° 41' 02.157" |
| Moulin à Baude Beacon | 6775.8 | 10A | beacon | 48° 09' 34.042" | 69° 39' 51.376" |

# Appendix F: MSD Graphical Aids

# *Methodology*

- Inspired by Canso Study
- Introduce "PIANC" and "Canadian waterways national manoeuvring guidelines"

# *Methodology*

- Three segments chosen for their different caracteristics:
  - Saguenay Entrance
  - Traverse du Nord
  - Trois-Rivières to Yamachiche
- Along the process, essential to confirm with the expert users

# *PIANC*

- Permanent International Association of Navigation Congresses
- The work group report is called "Approach Channels - A Guide for Design"

# PIANC

- In depth analyse of the important factors considered in the establishment of "Approach Channels"
  - Physical environment datas
  - Orientation, width and depth of the channel
  - Aids to navigation
  - Supported by the best mariner's practice

# *Our approach*

"To compare the actual width of a channel to a theorical width required for the safe passage of one or two vessels"

# CW over MSD

- CW - Channel width
- MSD - Minimum Safe Design

# *CW - Channel width*

- Channel template
- Larger in curves
- Minimal guaranteed depth

# CW - Channel Width

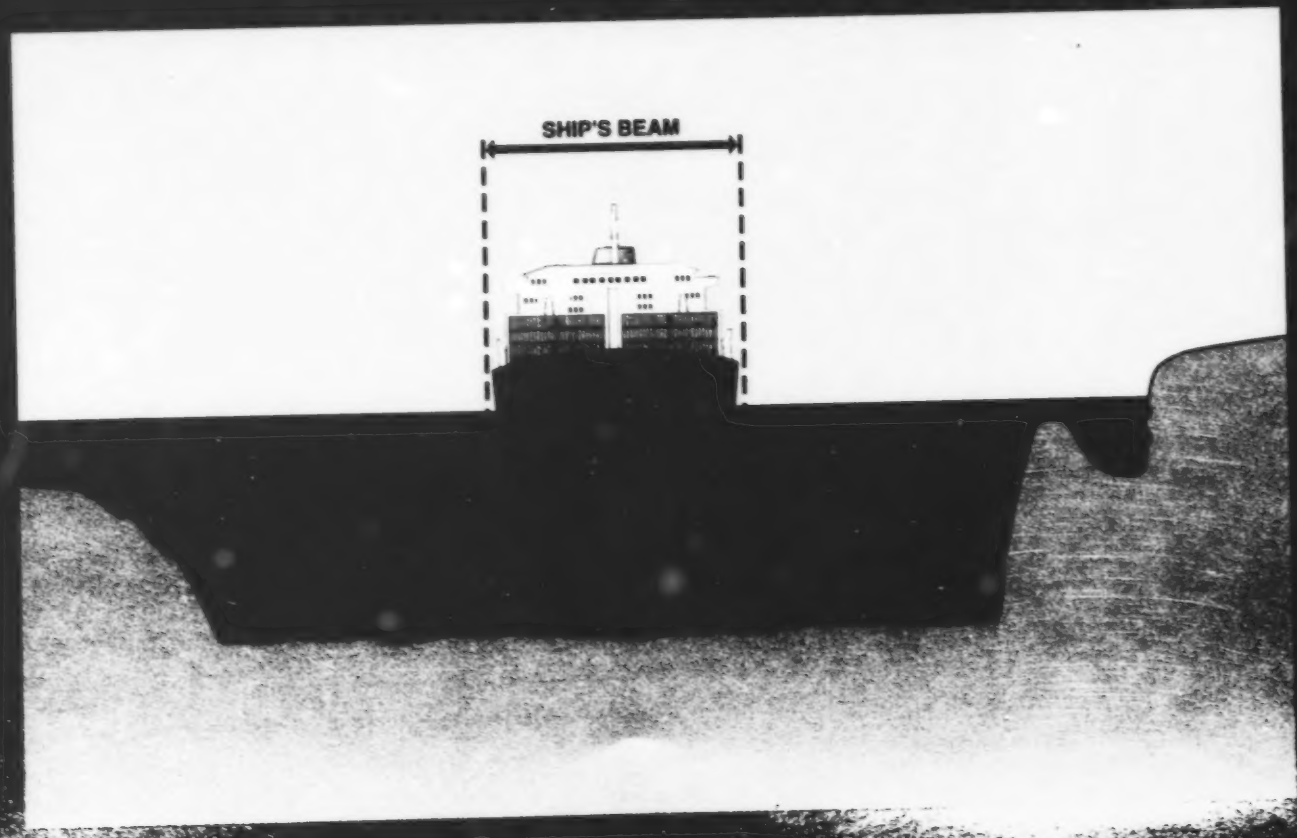
# *MSD - Minimum Safe Design*

- From the addition of three widths
  - 1- Physical dimension of the ship
  - 2- Manoeuvring space
  - 3- Quality of positioning

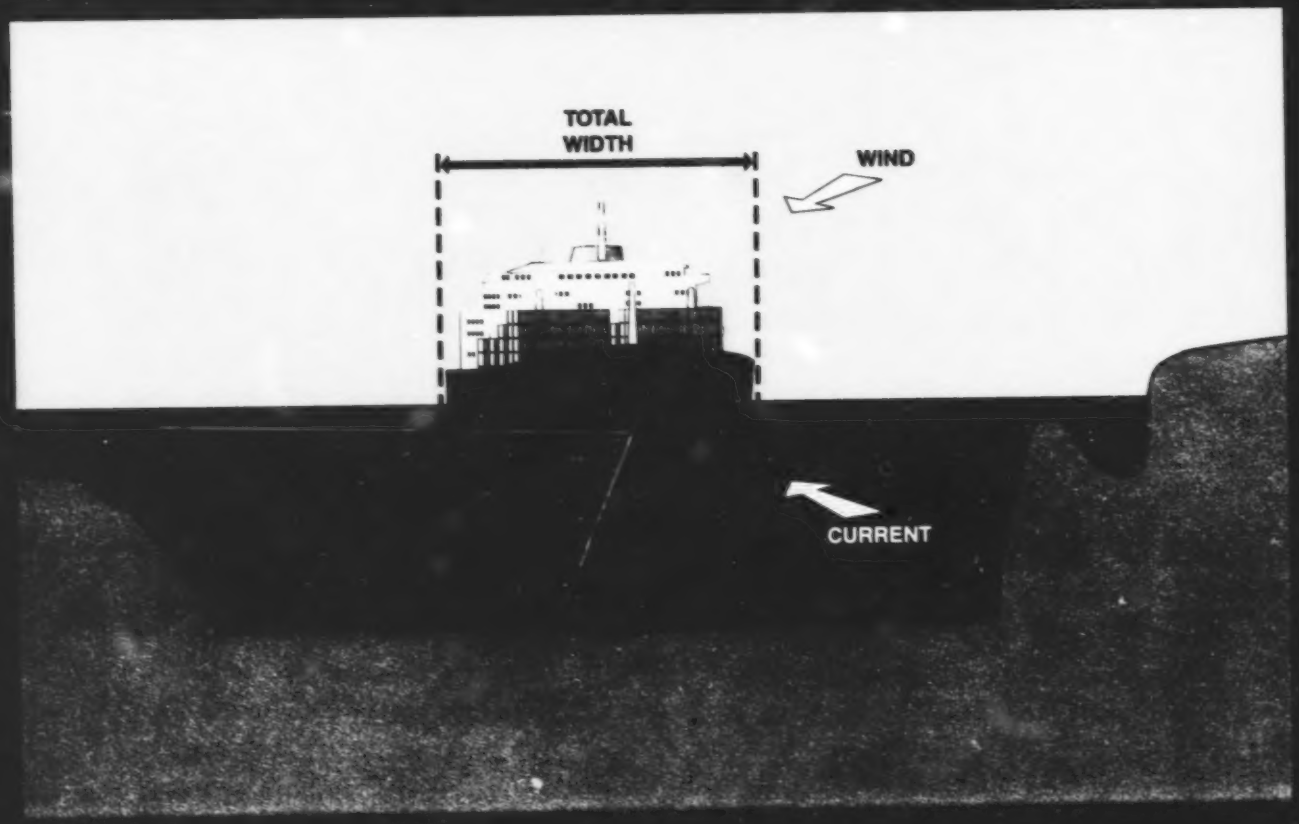
# 1- Physical dimension of the ship

- Molded breadth
- Plus the sum of the drifts
  - Due to wind
  - Due to current

# *Ship's beam (molded breadth)*



# *Plus the sum of drifts*

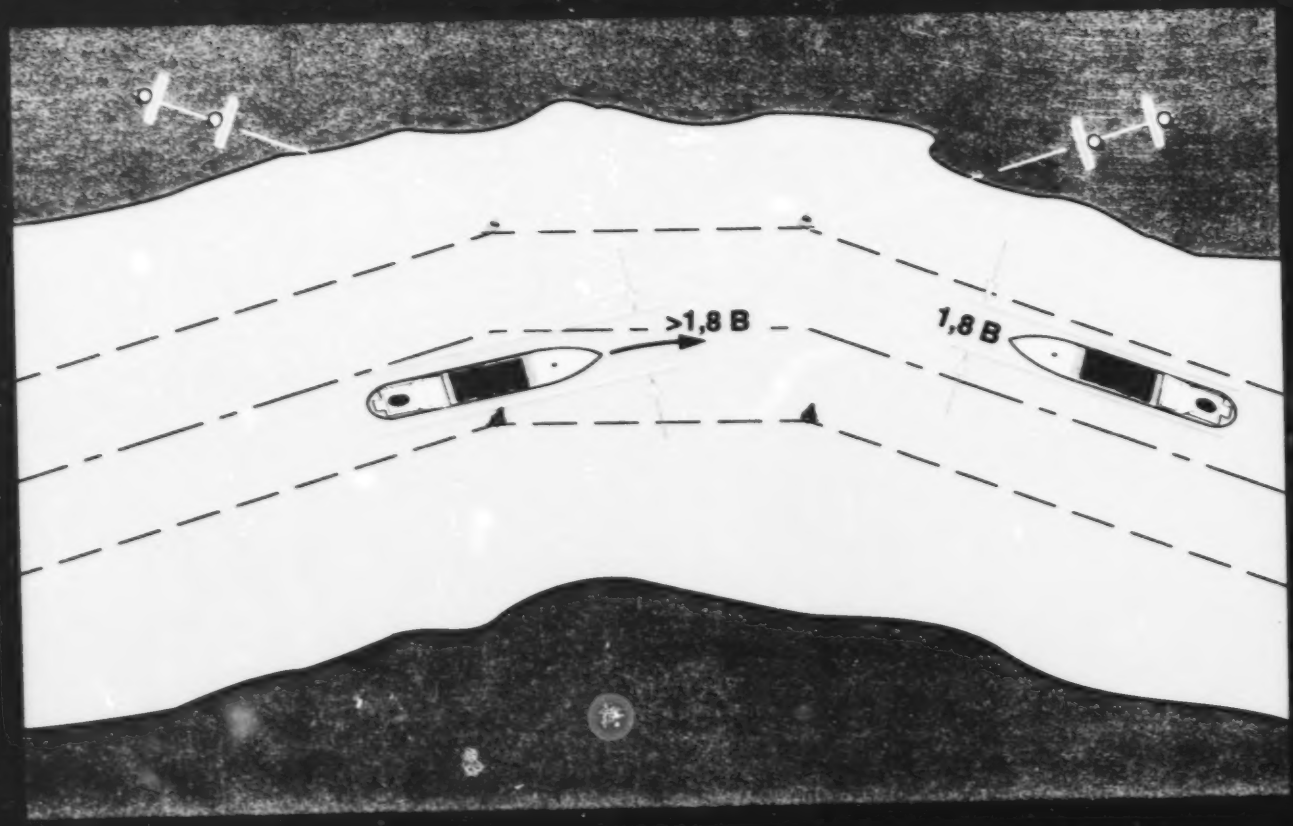


# *2- Shiphandling space*

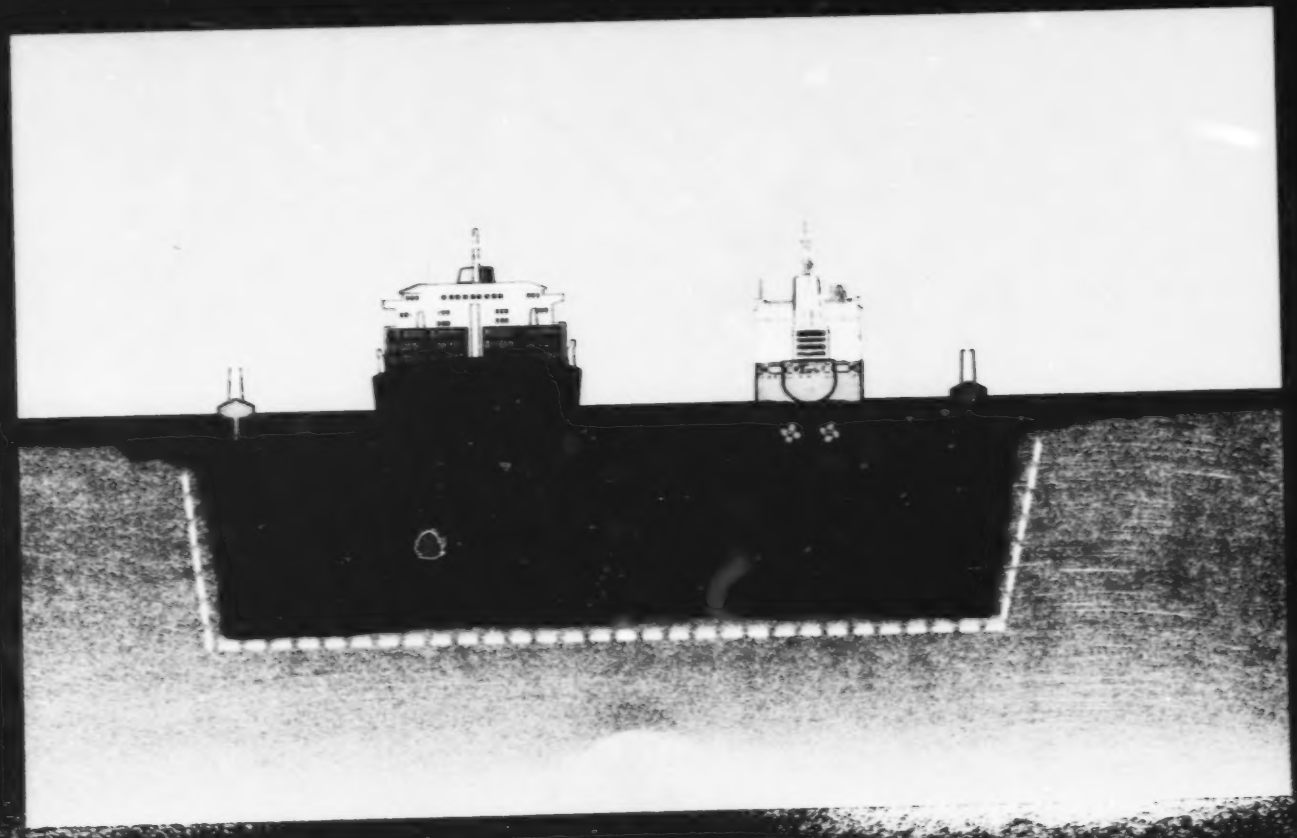
## Addition of many factors

- CW - Course keeping
- CW - Squat
- Distance to the channel limit
- Crossing or passing distance

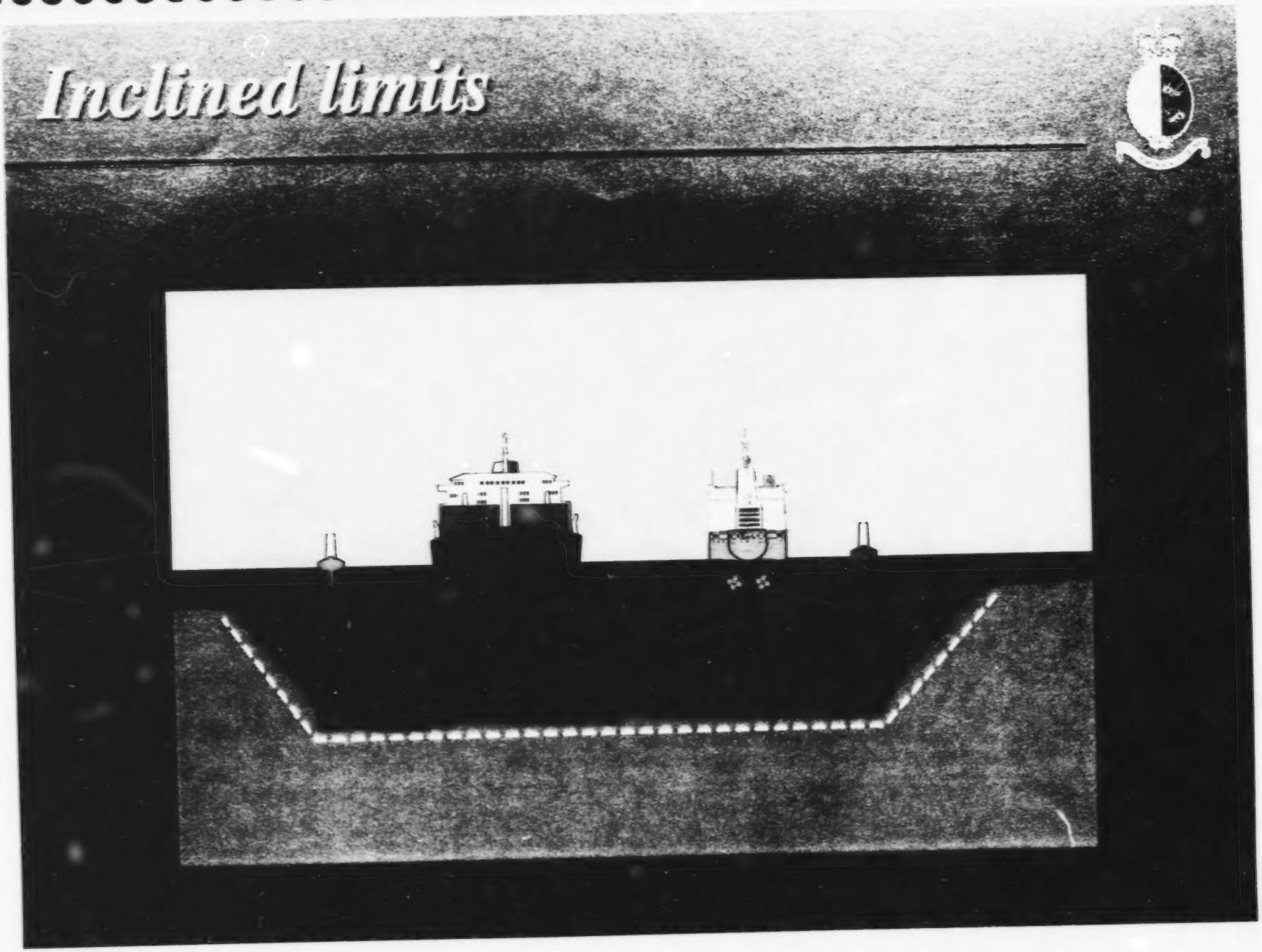
# Course keeping



# *Steep limits*

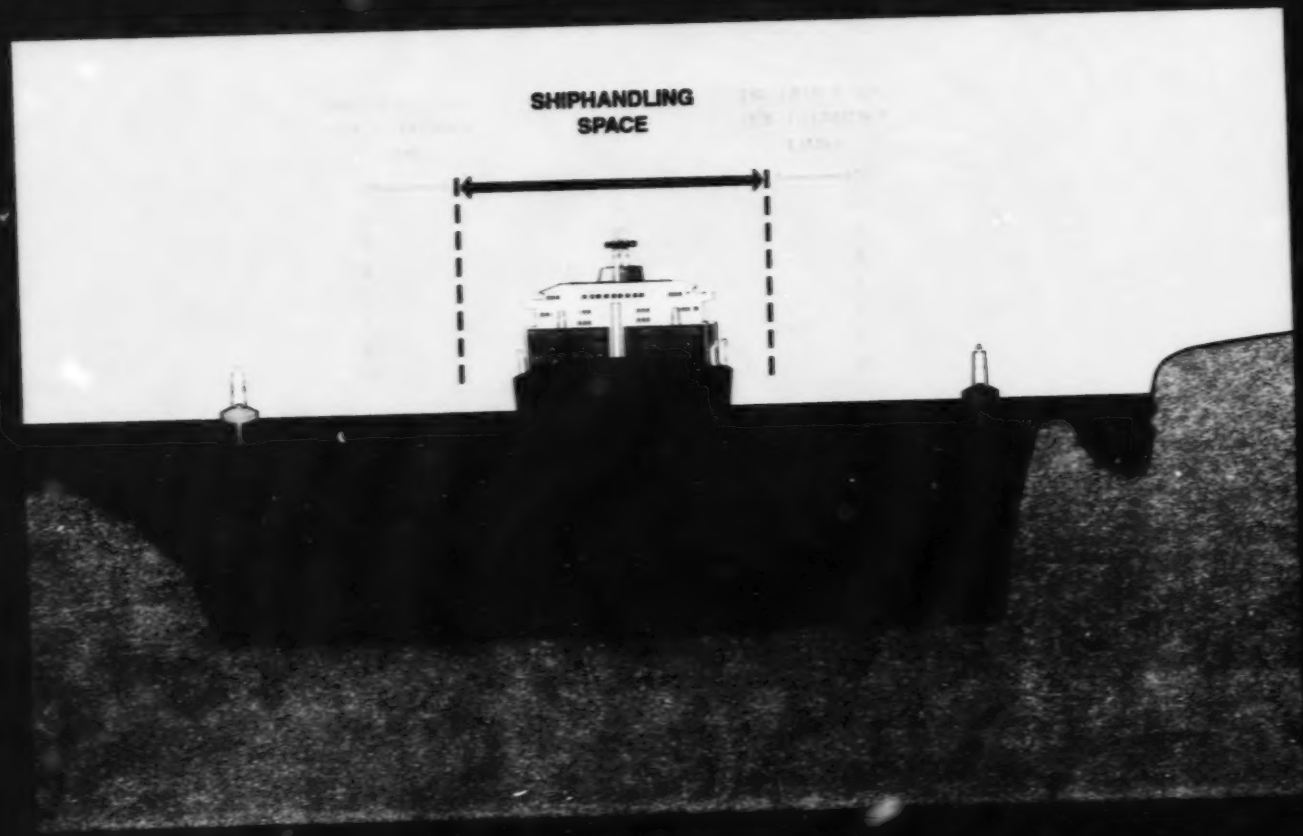


# Inclined limits

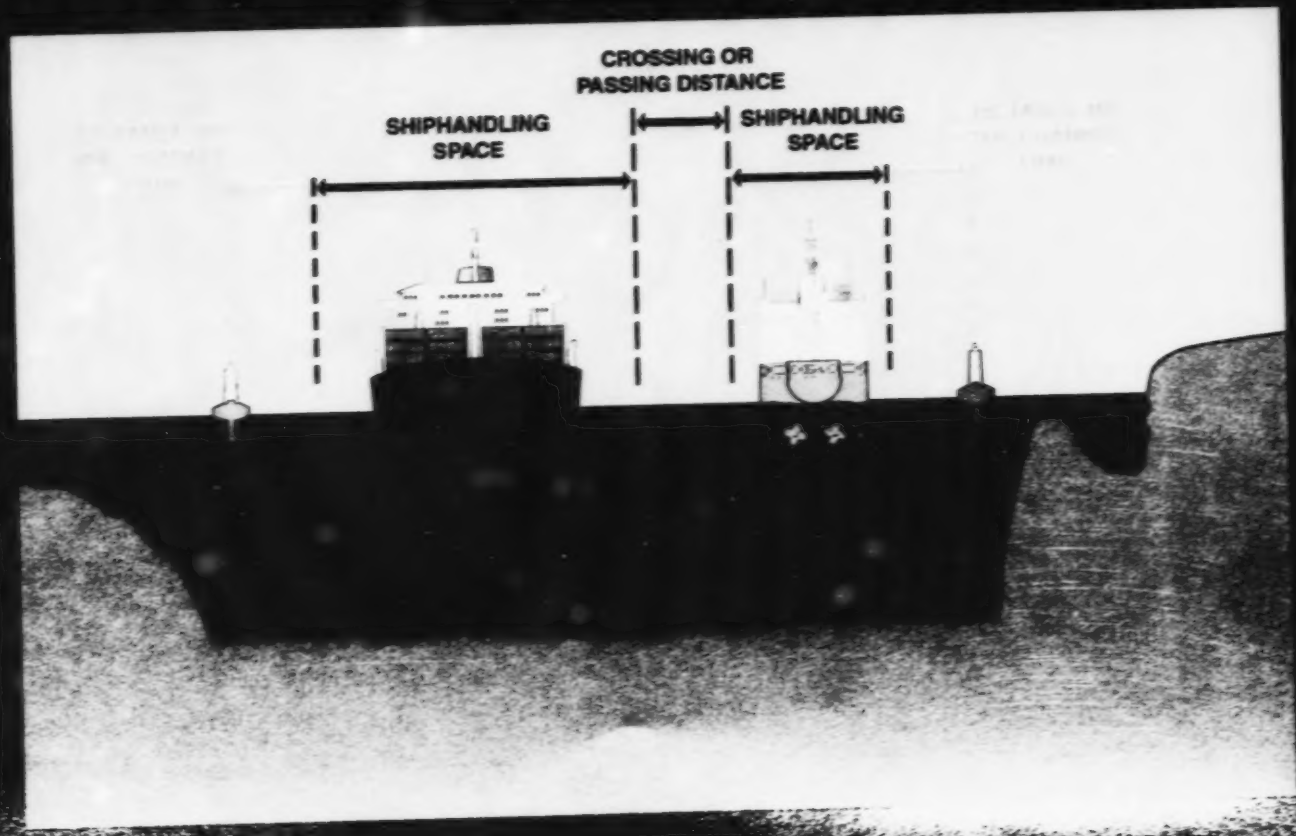


# *No limits (without effect)*

# *Passing of one ship*



# *Passing of two ships*



# 3- Positioning

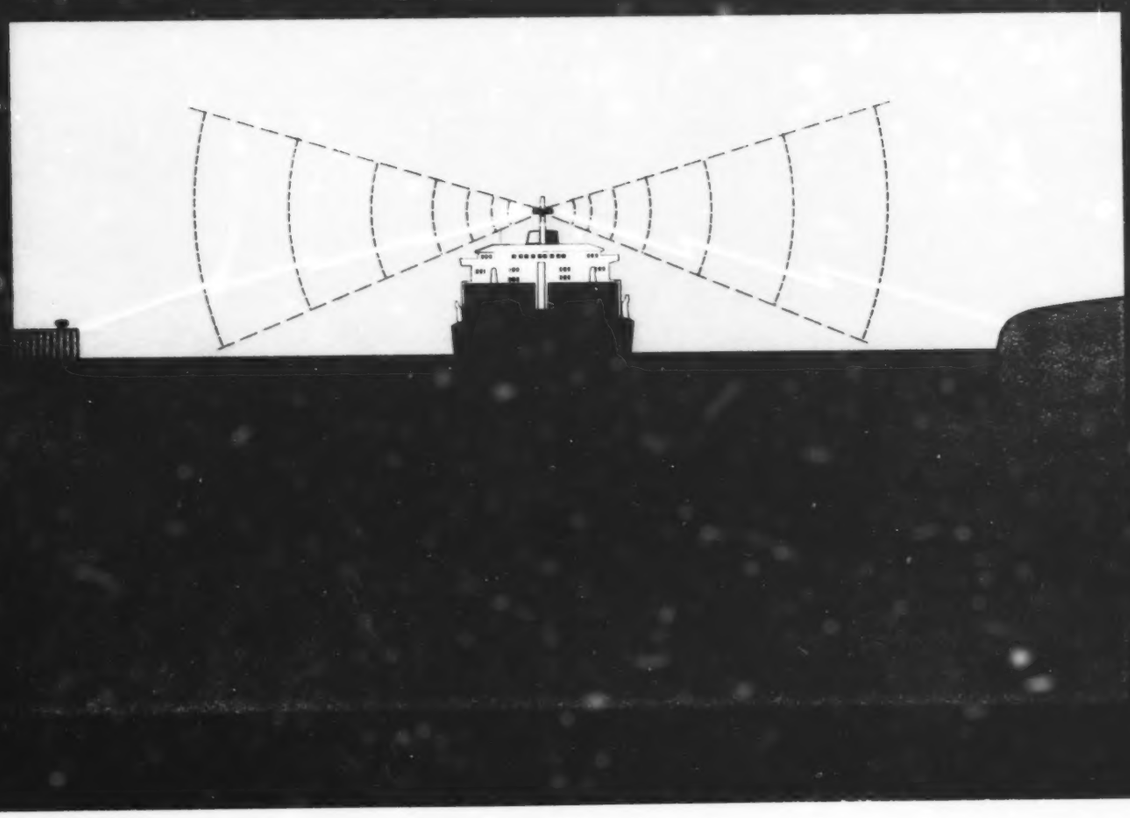
Positioning is the mariner's ability to determine with precision the location and the moving of his ship considering the existing conditions and the aids to navigation available and used.

# *Positioning*

- 2 methods considered
- Radar positioning
- Visual positioning
- Primary method and confirmation method

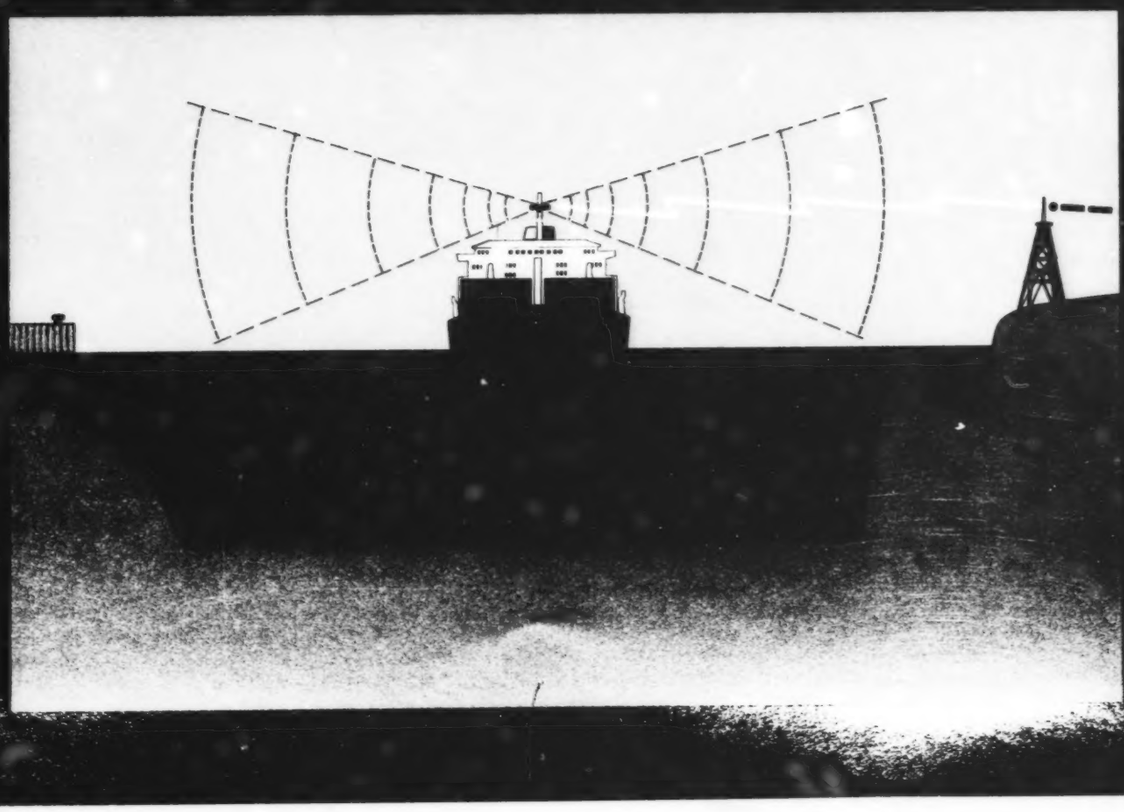
# *Radar Positioning*

How many good radar targets?



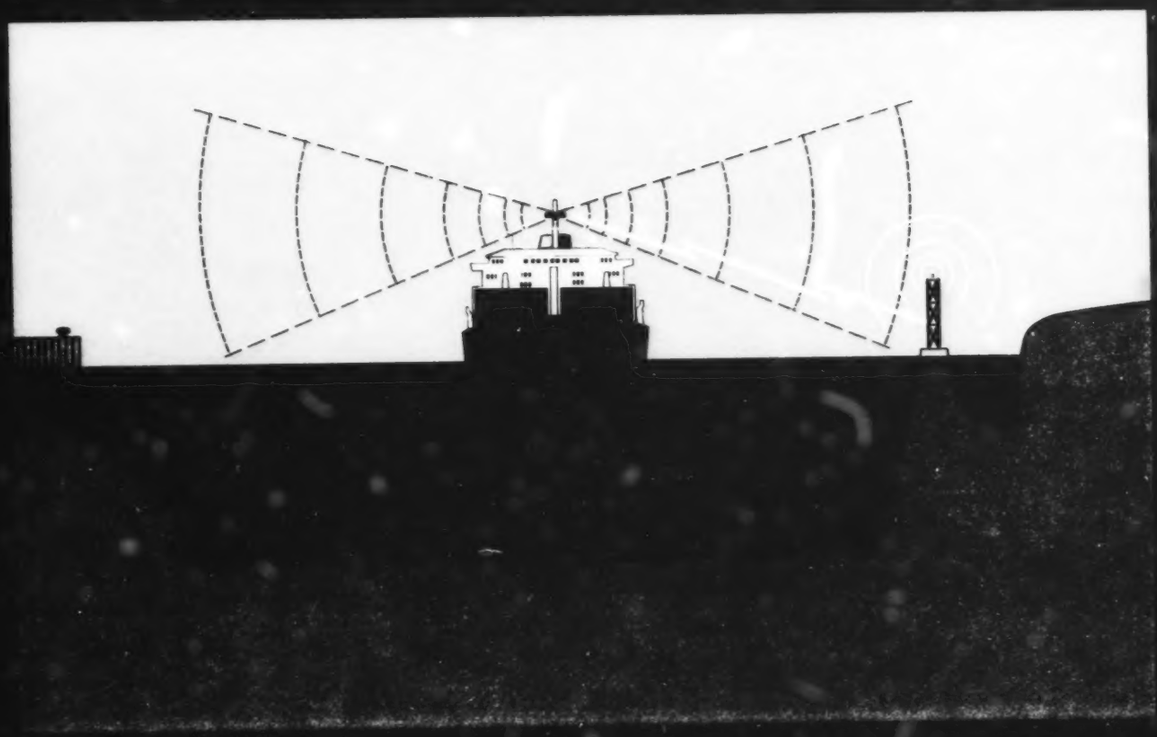
# *Radar Positioning*

How many racons?



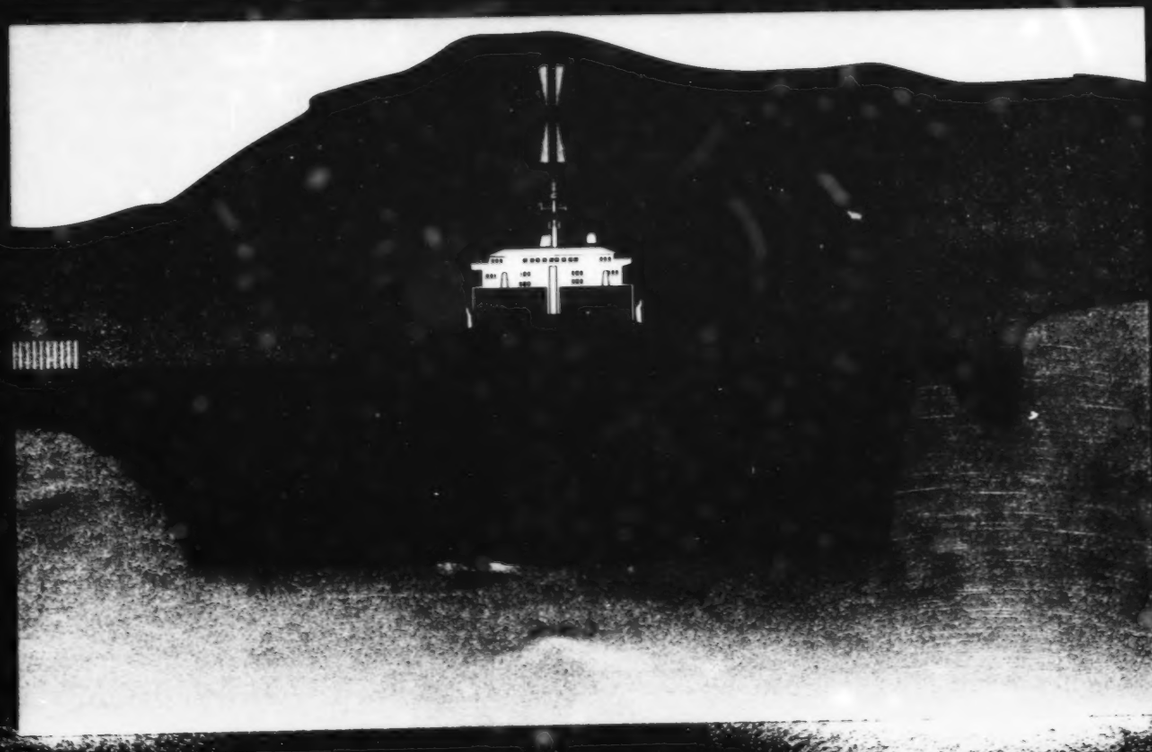
# *Radar Positioning*

How many fixed aids?



# *Visual Positioning*

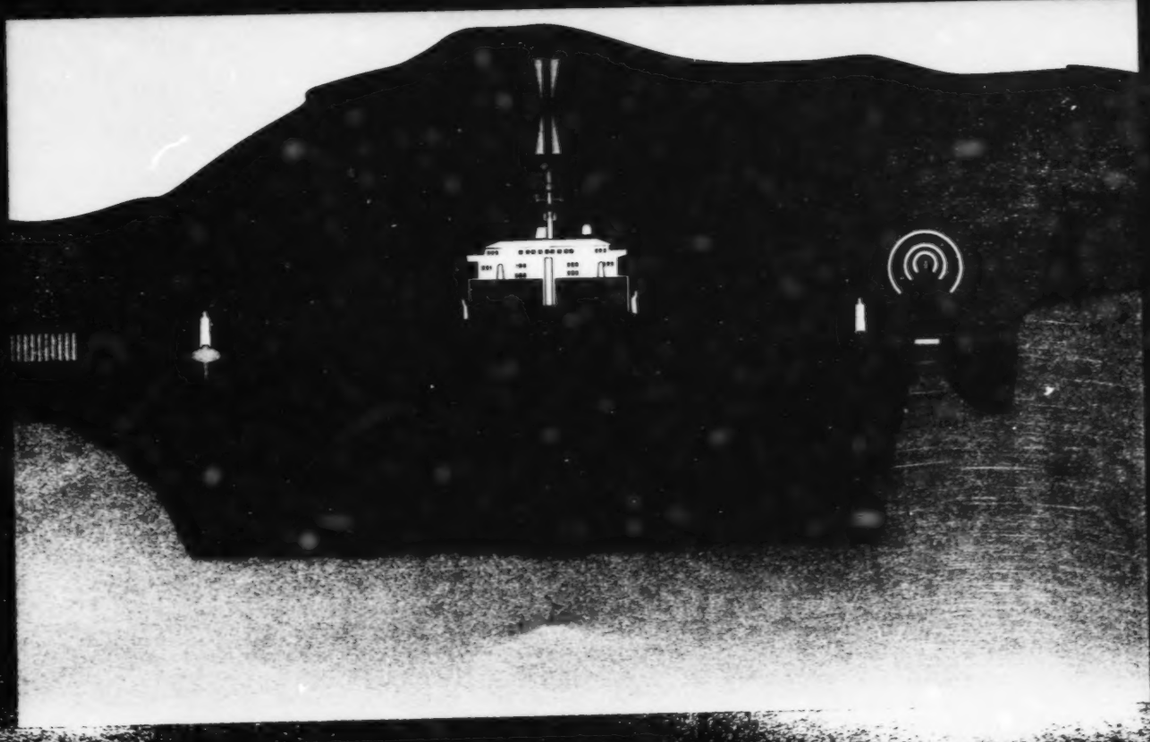
Are there visual marks or ranges available?



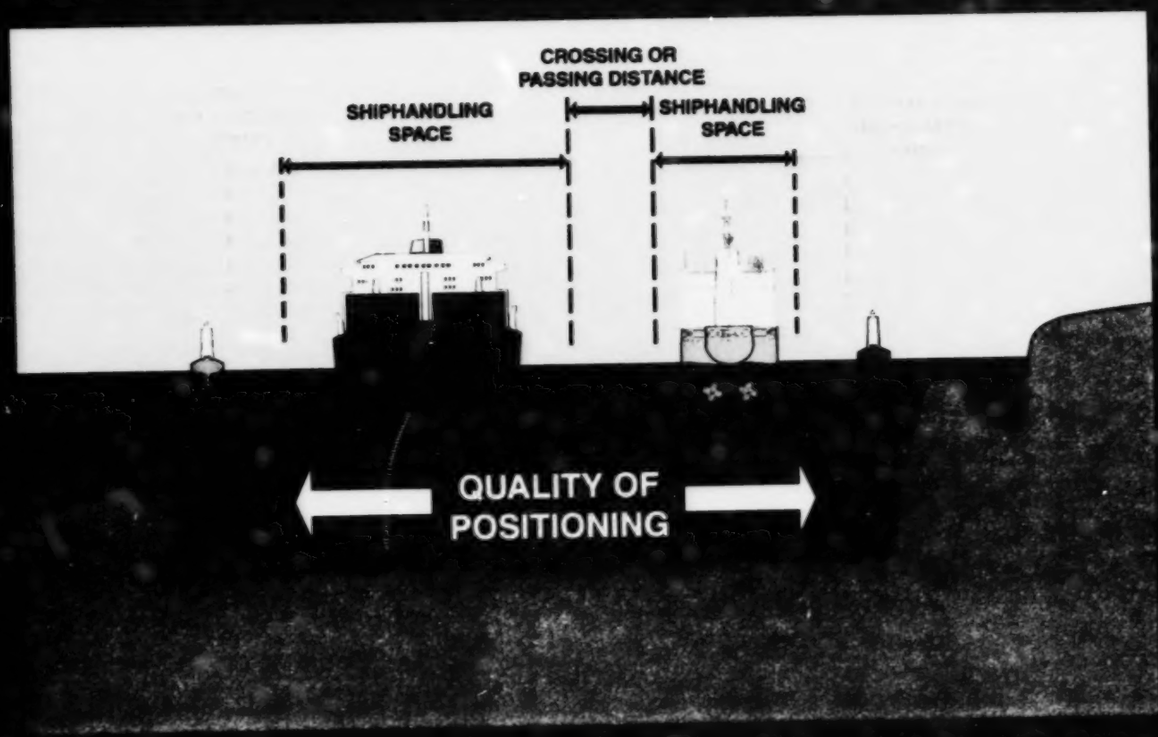
# *Visual and Radar Positioning*

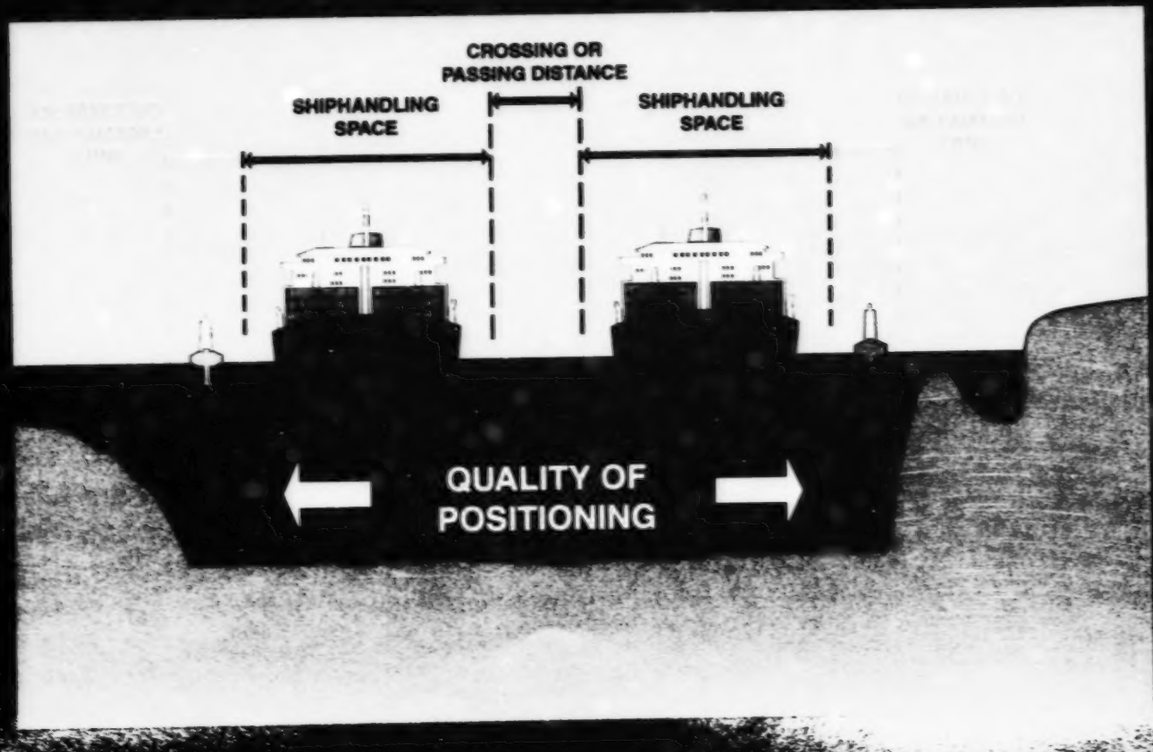
How many buoys?

# *Global Positioning*



# *CW/MSD > 1.0*




# *CW/MSD < 1.0*